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FC

TECHNICAL REPORT
EP-17

HANDBOOK OF FORT SHERMAN AND FORT GULICK, PANAMA CANAL ZONE

QUARTERMASTER RESEARCH & DEVELOPMENT CENTER
ENVIRONMENTAL PROTECTION DIVISION

JULY 1955

NATICK, MASSACHUSETTS

AD-   Accession No.

Quartermaster Research and Development Center, Natick, Mass. ENVIRONMENTAL HANDBOOK OF FORT SHERMAN AND FORT GULICK, PANAMA CANAL ZONE, by Selva C. Wiley, Arthur V. Dodd, and Jack V. Chambers. July 1955. 36 p., illus. (Technical Report EP-17)

Unclassified report

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Quartermaster Research & Development Center, U S Army
Natick, Massachusetts

ENVIRONMENTAL PROTECTION DIVISION

Technical Report
EP-17

ENVIRONMENTAL HANDBOOK OF FORT SHERMAN AND FORT GULICK, PANAMA CANAL ZONE

Selva C. Wiley
Geographer

Arthur V. Dodd
Meteorologist

Jack V. Chambers
Geographer

ENVIRONMENTAL RESEARCH BRANCH

Project Reference:
7-83-03-008D

July 1955

Foreword

This report is one of a series presenting environmental conditions at Army test sites, prepared at the request of the Test Coordinator, Research and Development Division, Office of The Quartermaster General. This report deals with the wet tropic environment of the Panama Canal Zone, and especially the areas contained within Fort Sherman and Fort Gulick. An attempt has been made to present as much of the information as possible in graphic or tabular form. The textual material is intended to supplement the graphs and maps and to describe certain elements of the environment which do not lend themselves to graphic presentation. It is anticipated that the environmental conditions described here will prove similar, if not wholly analogous, to those of other wet tropical areas.

Austin Henschel, Ph.D.
Acting Chief
Environmental Protection Division

Approved:

A. Stuart Hunter, Ph.D.
Scientific Director
QM Research & Development Command

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Abstract

This report presents a study of the environment of Fort Sherman and Fort Gulick in the Panama Canal Zone. The climate is humid tropical. An eight-month rainy period from May through December is followed by a four-month period of less rain from January through April. The diurnal temperature range is far greater than the mean annual range. Three major terrain categories have been distinguished: undulating uplands, drained lowlands, and undrained lowlands. Eighty per cent of the total area - 13,765 acres - is undulating uplands characterized by low rolling hills, narrow valleys, and steep hillsides. The surface material is predominantly a thick, plastic clay. Vegetation consists primarily of tropical evergreen forest on the undulating uplands and some form of marsh plants or swamp forest on the lowlands.

ENVIRONMENTAL HANDBOOK OF FORT SHERMAN AND FORT GULICK

1. Introduction

The Panama Canal Zone contains various installations of the U.S. Army, Navy, and Air Force. The portions with which this report is concerned are the Fort Sherman and Fort Gulick Military Reservations (location map, Fig. 1), both under Army control. Other areas that might be used for testing purposes include the Piña firing range south of Fort Sherman (Figs. 1, 2 and 3) and Dock 45, on the shores of Gatun Lake, within the Fort William D. Davis Military Reservation (Fig. 2). The Piña firing ranges are in very rugged terrain with considerable elevation, but are readily accessible over a good gravel road from Gatun Spillway.

The Fort Sherman Reservation includes some 12,000 acres bounded on the east by Limon Bay, on the south by the Rio Piña, and on the northwest by the Atlantic Ocean; the southeastern boundary is a surveyed line which roughly parallels the coast. The reservation is divided into two parts by the Rio Chagres, which enters the Caribbean about six miles southwest of Toro Point. The headquarters and permanent facilities of Fort Sherman are located at Toro Point, three miles west of Cristobal (the site of the Panama Canal Company's weather station which is the principal source of climatic data in this report) — situated at $9^{\circ}21'$N latitude and $7\cancel{0}^{\circ}54'$W longitude.
9

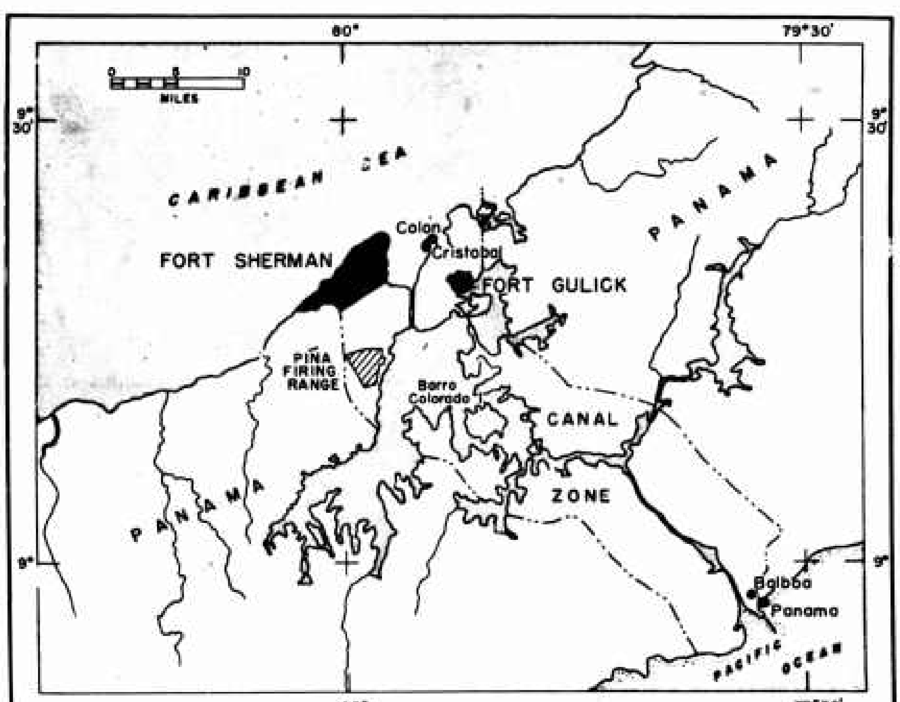

Figure 1: Location of Fort Sherman and Fort Gulick, Canal Zone.

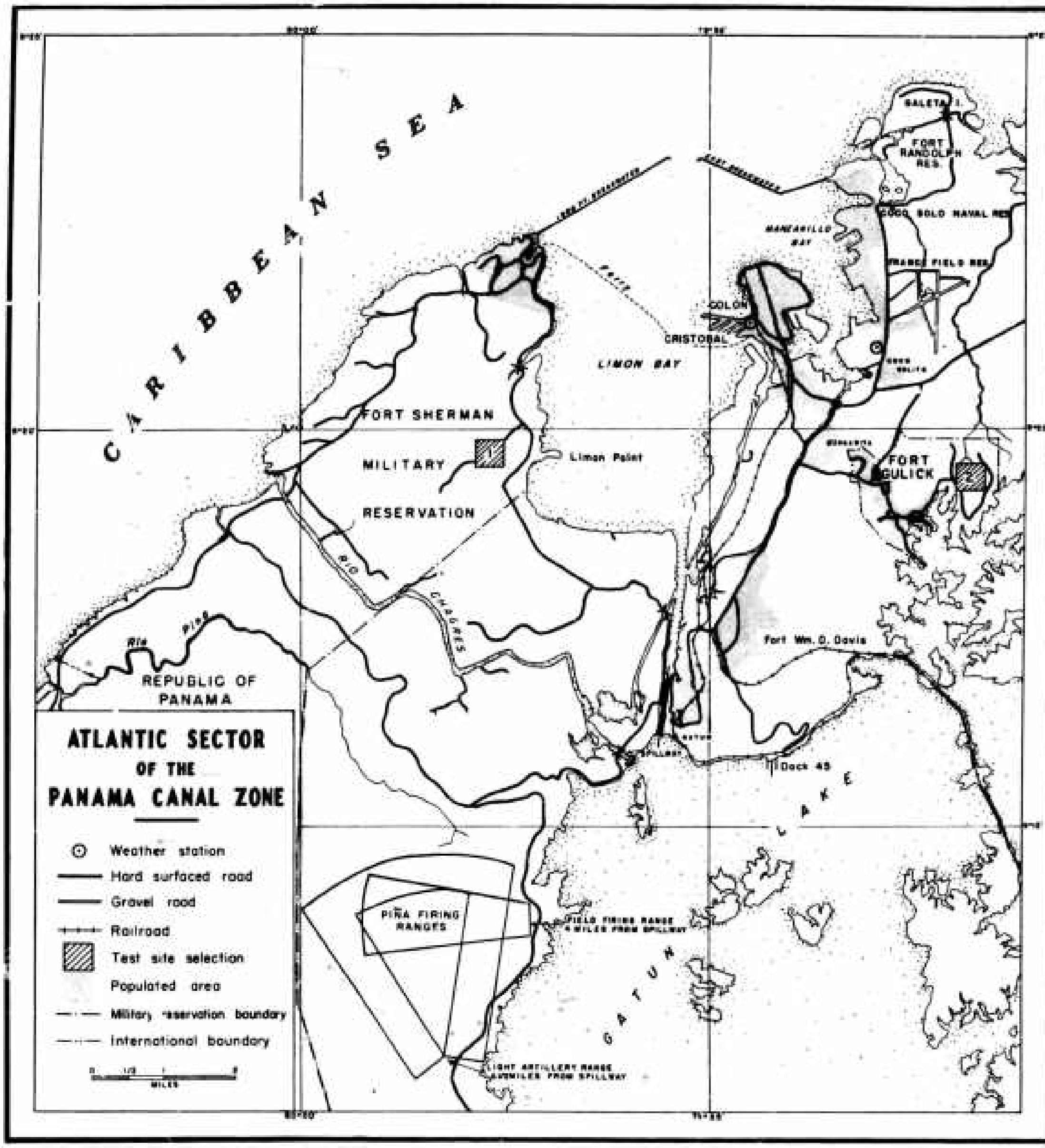

Figure 2: Atlantic Sector of the Panama Canal Zone - Cult re

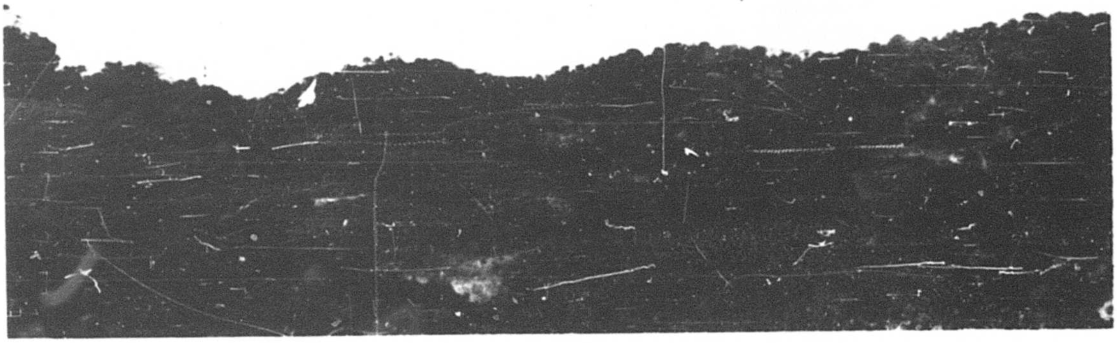

Figure 3: The Piña light artillery firing range, located outside the Fort Sherman Reservation in a region of rugged though low relief. The steep hills inclosing the basin are topped by towering trees. These giants with umbrella-like crowns stand far above the upper forest canopy which in itself averages perhaps 80 feet.

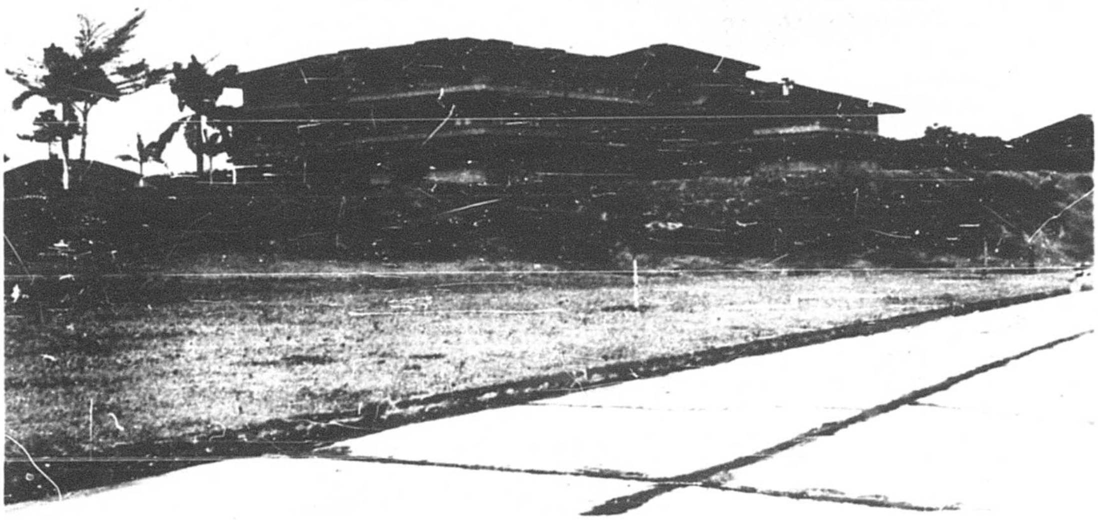

Figure 4: Housing is available at Fort Gulick in such buildings as this, overlooking Gatun Lake.

Fort Gulick, two miles southeast of Cristobal, contains 1,765 acres and is largely occupied by military installations. It is better equipped with housing facilities (Fig. 4) and access roads than Fort Sherman.

There are evidences of former testing activities at many places along the coast of the Fort Sherman Reservation. One of these is an abandoned antiaircraft position several hundred feet above the level of Limon Bay, about eight-tenths of a mile off the coastal road between Gatun and the base (Test Site 1, Fig. 2). In 1945, this area was used by the Artillery Tropical Testing Mission as a test site for various Army Technical Services, among them the Ordnance and Quartermaster Corps. At the conclusion of some eight months of testing, the site was again abandoned. Then in July 1946, the Naval Research Laboratory began using it. At the time of the field survey for this report (February 1953), a few facilities were still being maintained at this site by Navy Research Laboratory personnel, in spite of the fact that road maintenance had lagged to the point where the access road was almost impassable. The Department of the Army Site Evaluation and Planning Team, which visited the Canal Zone concurrently with the Office of The Quartermaster General survey team, selected the Naval Research Laboratory testing site at Fort Sherman for future wet-tropic testing. Their second choice was the ammunition storage area at Fort Gulick (Test Site 2, Fig. 2).

2. <u>Climate</u>

a. <u>General</u>. (Climatic Summary, Table I). The Isthmus of Panama has a tropical climate with consistently high but not extreme temperatures, high humidity, and abundant rainfall. From a climatic standpoint, the Atlantic Sector of the Isthmus, with heavier rainfall and less variation in temperature, affords the best sites for tropical testing. The following paragraphs and the graphs and tables in Appendix A apply to the Atlantic (north) side of the Canal Zone, and are generally representative of climatic conditions at Fort Gulick and Fort Sherman.

b. <u>Temperature</u>. Seasonal variations in the temperature regime are hardly perceptible (Fig. 5). Mean monthly values vary from 79.7°F in November, at the height of the wet season, to 81.7°F in April, at the end of the dry season, an annual variation of only two degrees. Diurnal temperature ranges are low, and can be expected to vary slightly from day to day. On a typical day the early morning minimum is about 76°F and the afternoon maximum about 85°F. The constancy of the temperature regime is further illustrated by the fact that the absolute range in this section of the Canal Zone is only 29 degrees, the absolute minimum being 66°F and the absolute maximum being 95°F. Frequencies of extreme temperatures for two representative months, March and November, are presented in Appendix A.

TABLE I: CLIMATIC SUMMARY FOR CRISTOBAL, CANAL ZONE
(Elevation 36 feet)*

TEMPERATURE (°F)

Month	Mean	Record Highest	Record Lowest	Daily Range	Number of Days Max. 85°F	Number of Days Min. 75°F
Jan	80	88	70	8	15	6
Feb	80	90	69	8	13	5
Mar	81	92	67	8	18	3
Apr	82	94	72	8	18	3
May	81	95	71	10	21	6
Jun	81	93	68	10	19	9
Jul	81	91	70	9	18	9
Aug	81	93	70	10	16	10
Sep	81	94	70	11	19	11
Oct	80	95	70	11	20	16
Nov	80	92	69	9	13	16
Dec	80	90	66	8	16	10

PRECIPITATION

Month	Amount (inches) Mean	Max. Monthly	Min. Monthly	Max. Daily	Max. Hourly	Number of Days With .01	.25 in.	1 in.
Jan	3.4	19.2	.3	3.4	1.8	16	3	1
Feb	1.5	12.4	**	7.9	1.8	14	2	***
Mar	1.5	9.2	**	3.5	1.7	12	1	***
Apr	4.1	21.7	.3	5.4	2.8	15	4	1
May	12.5	23.0	1.6	7.6	4.4	21	11	4
Jun	13.9	31.2	6.4	8.5	3.1	24	13	5
Jul	15.6	27.7	4.4	6.8	3.4	25	12	5
Aug	15.3	26.6	5.8	6.9	5.2	25	13	5
Sep	12.8	23.0	5.4	7.5	3.6	23	12	4
Oct	15.8	42.2	5.8	11.0	4.9	24	14	6
Nov	22.3	43.1	6.6	9.8	4.4	25	16	8
Dec	11.7	34.4	.9	10.3	3.5	22	8	3

Month	REL. HUMIDITY (%) Mean (Bihourly)	WIND (MPH) Mean Speed	Prev. Dir.	Max. Speed	CLOUDINESS (NO. OF DAYS) Clear	Partly Cloudy	Cloudy	SUNSHINE Av. Hours	% of Possible
Jan	78	14	N	34	9	18	4	8	69
Feb	77	15	N	32	8	17	3	8	71
Mar	77	15	N	30	10	17	4	9	73
Apr	79	13	N	37	5	16	9	8	62
May	83	8	N	30	1	13	17	6	44
Jun	85	7	SE	29	1	9	20	5	39
Jul	86	8	N	32	1	9	21	5	38
Aug	86	8	W	35	1	11	19	5	43
Sep	85	6	SE	31	1	12	17	6	47
Oct	85	7	SE	32	2	11	18	5	44
Nov	86	8	W	38	2	11	17	5	42
Dec	82	11	N	35	6	16	9	7	59

*Length of records: All number of days and sunshine items: 20 yrs.; Temperature Means and Extremes, and Relative Humidity: 41 yrs.; Wind: 36 yrs.; Precipitation Monthly Means and Extremes: 73 yrs.; Daily and Hourly Extremes: 37 yrs. **Less than .05 in. *** Less than .5.

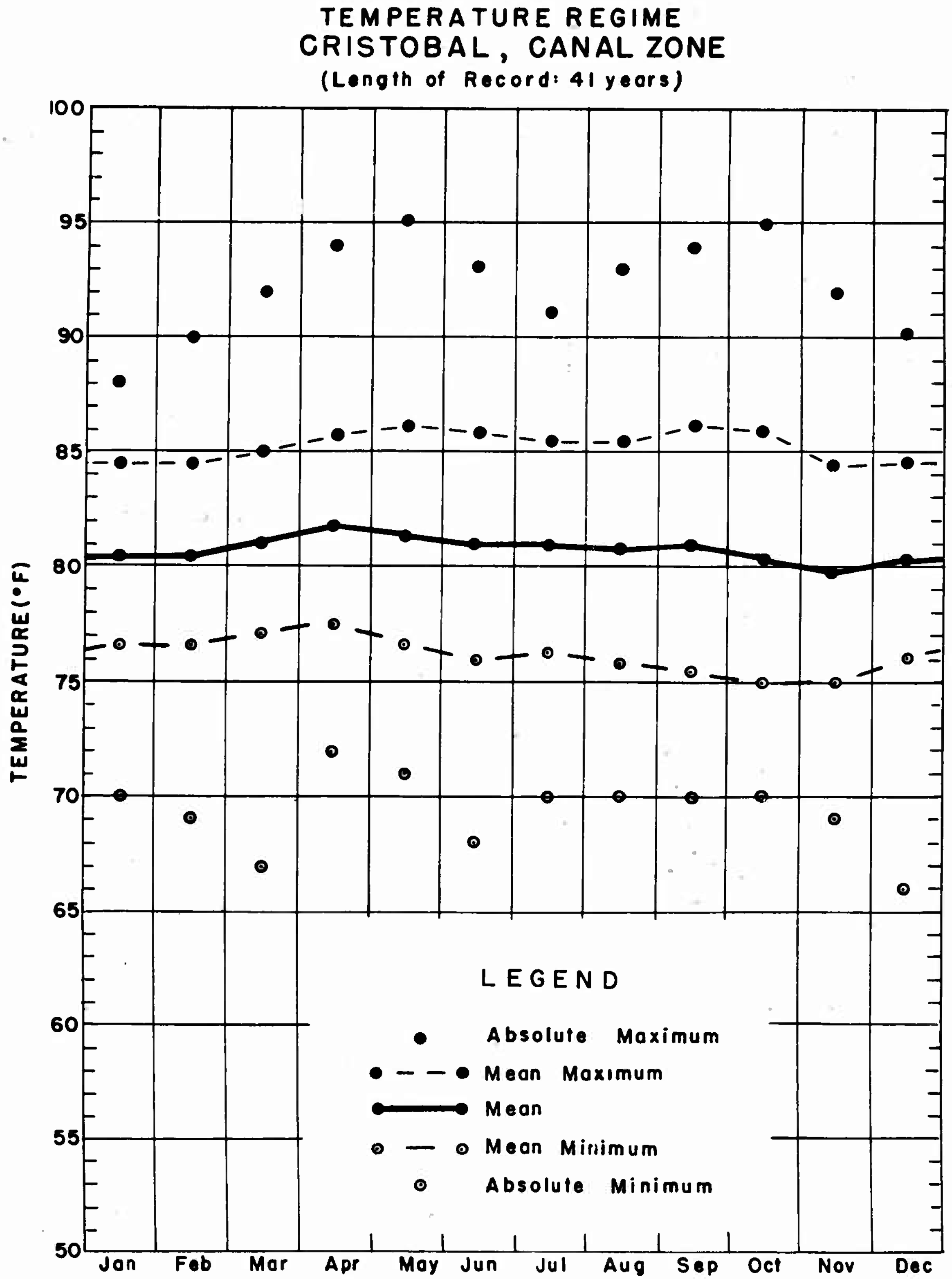

Figure 5: Temperature Regime - Cristobal, Canal Zone

c. Precipitation. The annual migration of the northeast trade wind belt and the intertropical front normally divides the year into a 4-month dry season (from late December to late April) and an 8-month rainy season (the remainder of the year). Mean precipitation total for each of the wet season months is in excess of 10 inches, and actual totals for any particular month during the wet season may exceed 20 inches (Fig. 6). In both October and November, the peak of the wet season, more than 40 inches of rain has been recorded. Of the dry months, February and March receive the least rain; the mean totals are 1.5 inches. However, the so-called "dry season" is a misleading term, for during some years the dry season can be very dry and in others very wet. For example, in February, monthly precipitation totals have ranged between 0.04 and 12.37 inches over a 73-year period. Normally rain falls on about half the days of the "dry season."

d. Humidity. The relative humidity is notably high, varying from an average in the high 70's from January through April to the middle 80's from May through December (Fig. 7). During the latter months the average for the early morning hours is above 90 percent. Dewpoints show a similar trend from dry season to wet season, ranging from an average of 72°F in February to 76°F in July (Fig. 8).

e. Winds. Winter and spring are dominated by the northeast trade winds, with the northern component prevailing. Mean monthly velocities are highest during this period; February and March each have 15 mph averages (Figs. 9 and 10). By May the zone of doldrums has moved northward into this region and winds become light and variable, averaging less than 10 mph.

f. Cloudiness, sunshine, and radiation. Daytime cloudiness averages annually about 7/10 of complete sky coverage. During the rainy season more than half the sky is covered 85 to 90 percent of the time, and during the dry season about 50 percent of the time. Although the percentage of cloudiness is high, there are few days without some sunshine. Cristobal averages 6.3 hours of sunshine per day or 53 percent of the possible, with monthly totals ranging from about 5 hours per day in June, July, and November to about 9 hours per day in March (Table II).

g. Visibility. More than 90 percent of the time visibility is equal to or greater than 6 miles. The major obstruction to visibility is rain; others, such as, fog, smoke, haze and dust, are rare.

h. Storms. Cold air masses, accompanied by widespread cloudiness, low ceilings and visibilities, and rain-showers, occasionally penetrate as far south as the Canal Zone in winter.

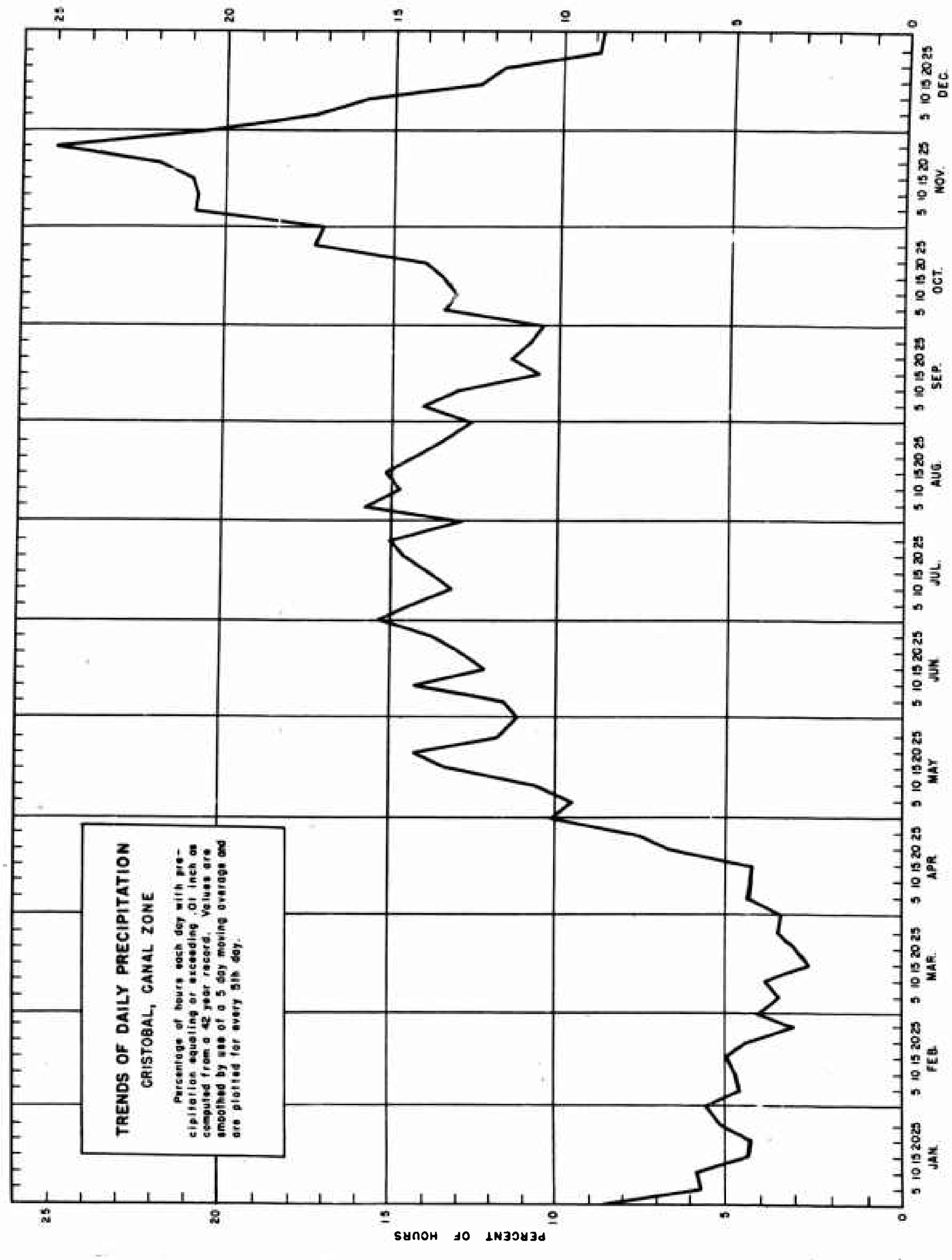
TRENDS OF DAILY PRECIPITATION
CRISTOBAL, CANAL ZONE
Percentage of hours each day with precipitation equaling or exceeding .01 inch as computed from a 42 year record. Values are smoothed by use of a 5 day moving average and are plotted for every 5th day.
PERCENT OF HOURS
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.

Figure 6

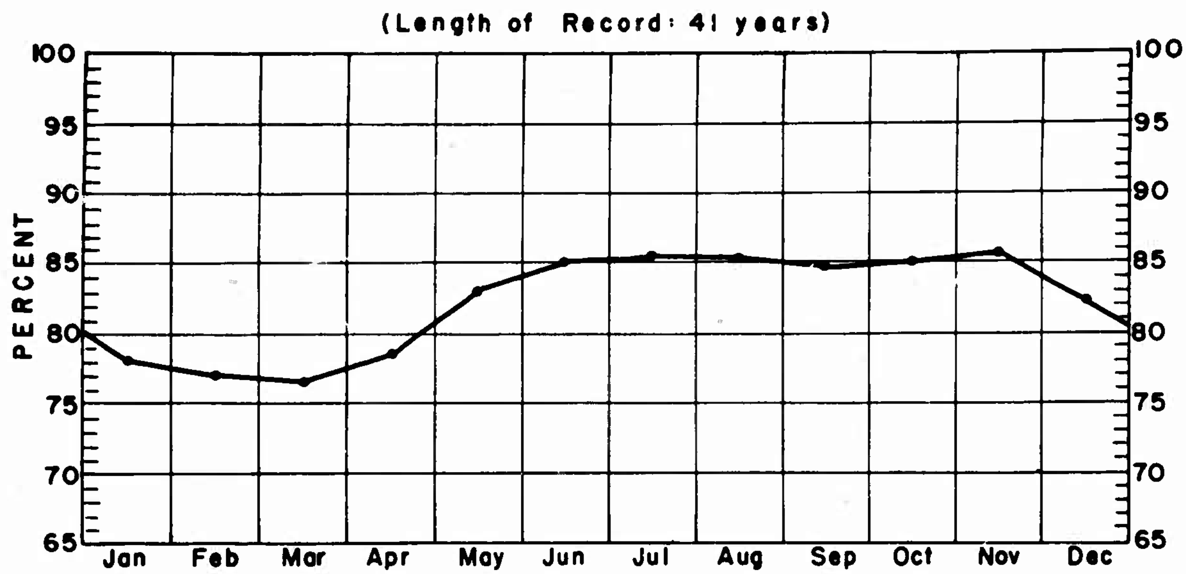

Figure 7: Mean Relative Humidity - Cristobal, Canal Zone

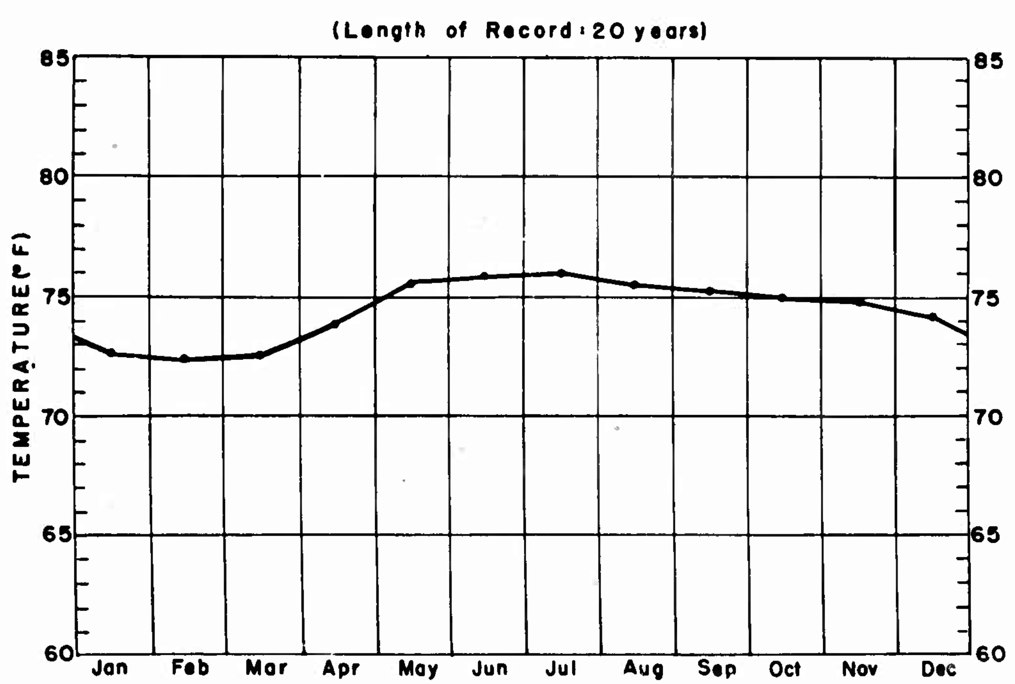

Figure 8: Mean 0800 Dewpoint Temperature - Cristobal, Canal Zone

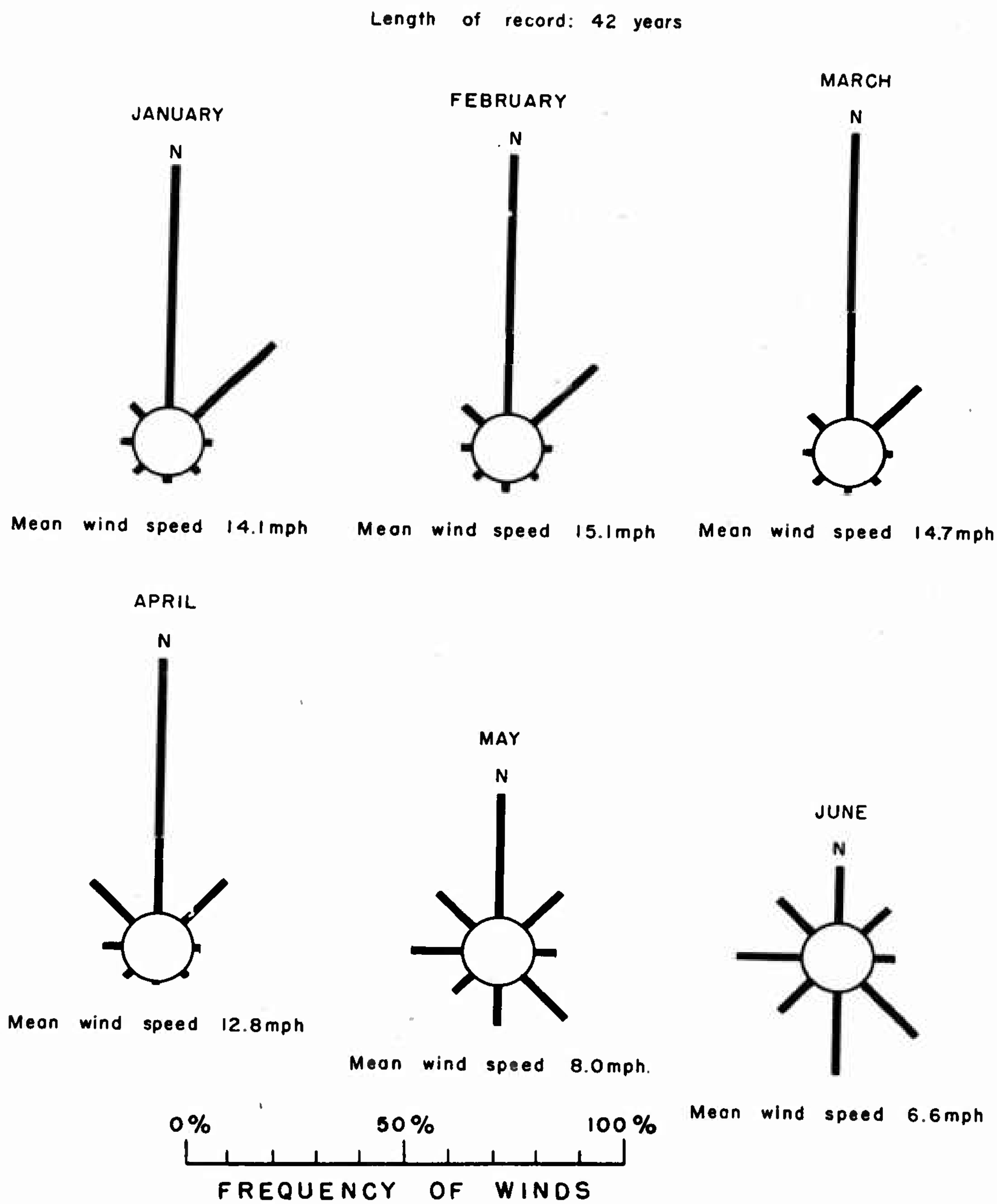

Figure 9: Surface Winds Percentage Frequency of Occurrence by Direction - Cristobal, Canal Zone (Jan. - June).

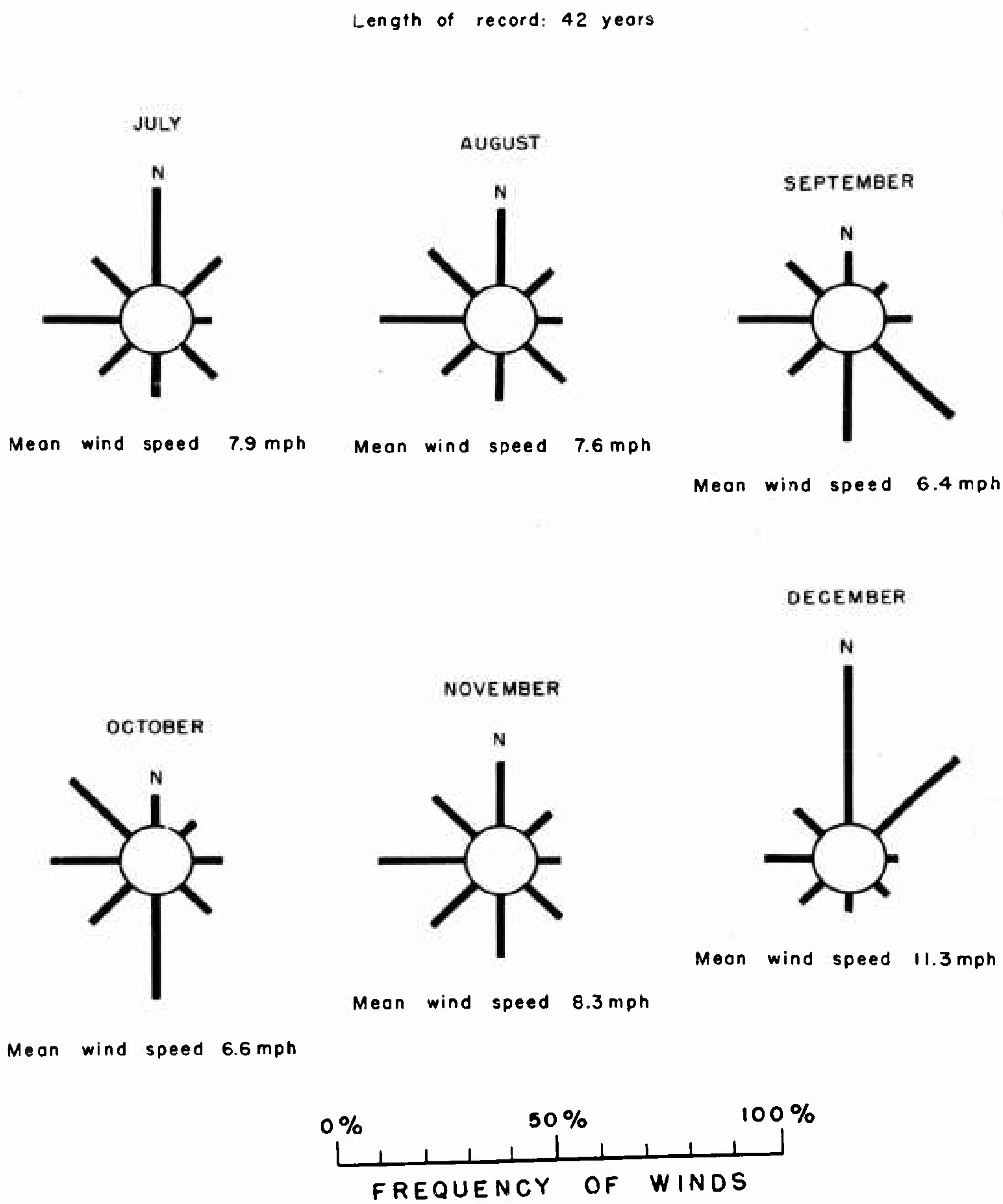

Figure 10: Surface Winds Percentage Frequency of Occurrence by Direction - Cristobal, Canal Zone (July - Dec.).

TABLE II: MEAN FREQUENCY OF OCCURRENCE (DAYS) OF THUNDERSTORMS AND VARIOUS TYPES OF SKY COVER CRISTOBAL, CANAL ZONE

MONTH	Thunder-storms	Light fog*	Clear skies**	Cloudy skies***
Jan	0.0	0.0	8	4
Feb	0.0	0.0	8	3
Mar	0.1	#	9	5
Apr	2.1	0.1	4	10
May	11.8	#	1	18
Jun	15.0	0.1	1	21
Jul	15.8	0.0	1	22
Aug	15.8	0.1	0	21
Sep	14.9	#	1	18
Oct	13.7	0.1	2	19
Nov	7.6	0.1	2	18
Dec	2.5	0.1	6	9
Total	99.3	0.6	43	168

*Dense fog never occurred.
**Clear skies, less than 0.4 sky cover.
***Cloudy skies, greater than 0.7 sky cover.
#Less than 0.05 days.

Length of record: 25 years for light fog, 29 years for other observations.

Their invasion as a rule results only in an intensification of the northeast trades, and although winds may reach gale force along the Atlantic Coast, little damage is reported. Thunderstorms occur frequently from May through October, during which period occur an average of 87 of the annual average of 99 storms (Table II). At times the thunderstorms are very intense, with strong, gusty winds and severe lightning, but damage is seldom reported. Hurricanes, common in the Caribbean, have never been reported as far south, in Central America, as the Canal Zone.

i. Microclimate of the forest. The climatic data presented in this study were obtained in the open under standard conditions of height, ventilation, and radiation shielding. Within the forests (Fig.11), conditions differ greatly from those in the open. One of the most notable microclimatic features of the tropical forest is the stillness of the air near ground level. During a 23-day test at Barro Colorado Island (Fig. 1) about 20 miles inland from the Caribbean Sea, average wind movement at six feet above the ground in the forest was less than one mph. Average wind speed in a nearby open area was about 10 mph. During this test the minimum temperature was 79°F and the maximum 81°F. Humidities within the sheltered stillness of the forest (Fig.12) are high, creating an oppressiveness which could be of primary concern in test planning. Therefore, all plans for forest testing should include provisions for on-the-spot meteorological observations.

3. Surface and Terrain

a. General. Three major categories of terrain have been distinguished in the study area (Fig. 13 and Table III). These are (1) Undulating Uplands, comprising the whole of Fort Gulick and about four-fifths of the Fort Sherman Reservation (Fig. 3); (2) Drained Lowlands, on the eastern side of Fort Sherman bordering Limon Bay (Fig. 14); and (3) Undrained Lowlands, located principally along the banks of the Rio Chagres (Fig. 15). A fourth type, designated the Coastal Fringe, occupies little area but includes some very conspicuous terrain features (Fig. 16); in this category are grouped the sandy beaches, escarpments and cliffs, tidal flats, and coral reefs around the periphery of Fort Sherman.

Between 80 and 90 percent of the surface materials of Fort Sherman and Fort Gulick consist of thick moderately plastic clays with thin, organic-rich surfaces. The remaining portion consists of alluvium, muck, sand, or coral. Gatun clay, which is widespread throughout these areas, is composed of materials weathered from the underlying sedimentary rocks. This clay is uniformly red, moderately friable, and has a thin layer of brownish-red, friable soil at the surface. There is little change in the subsoil down to a depth of about five feet, but below this is a soft, decomposed parent material consisting of decayed rock and clay.

Figure 11: Luxuriant vegetation along the road from Fort Sherman to the Rio Chagres through the Undulating Uplands.

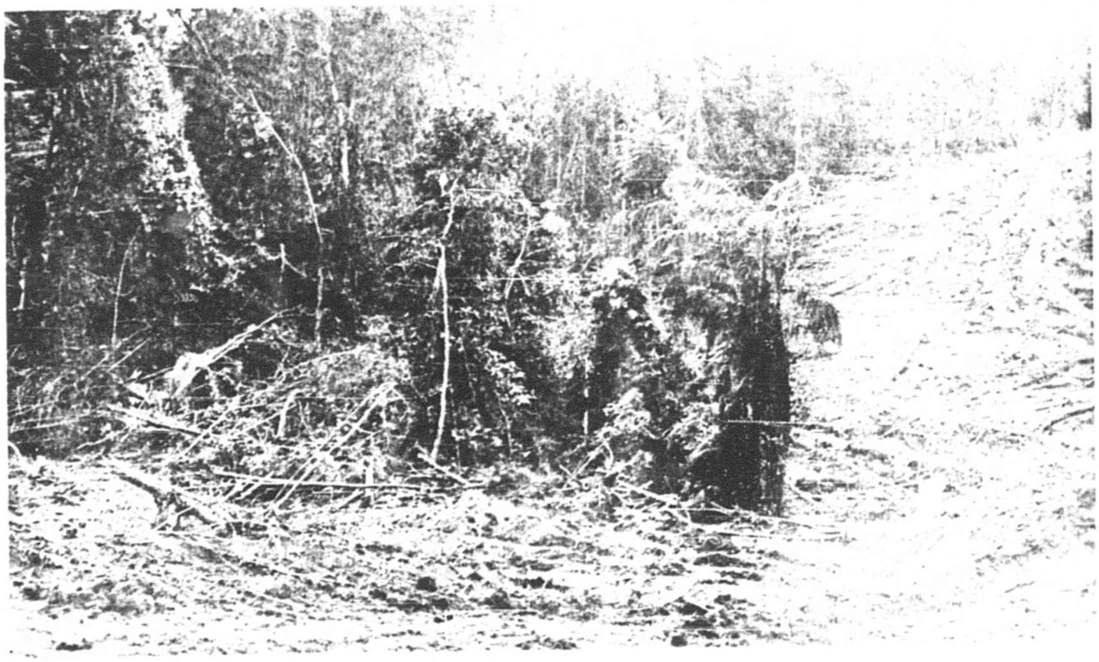

Figure 12: Dense Tropical Evergreen Forest at the edge of a clearing. Such forest is common throughout the Panama Canal Zone area.

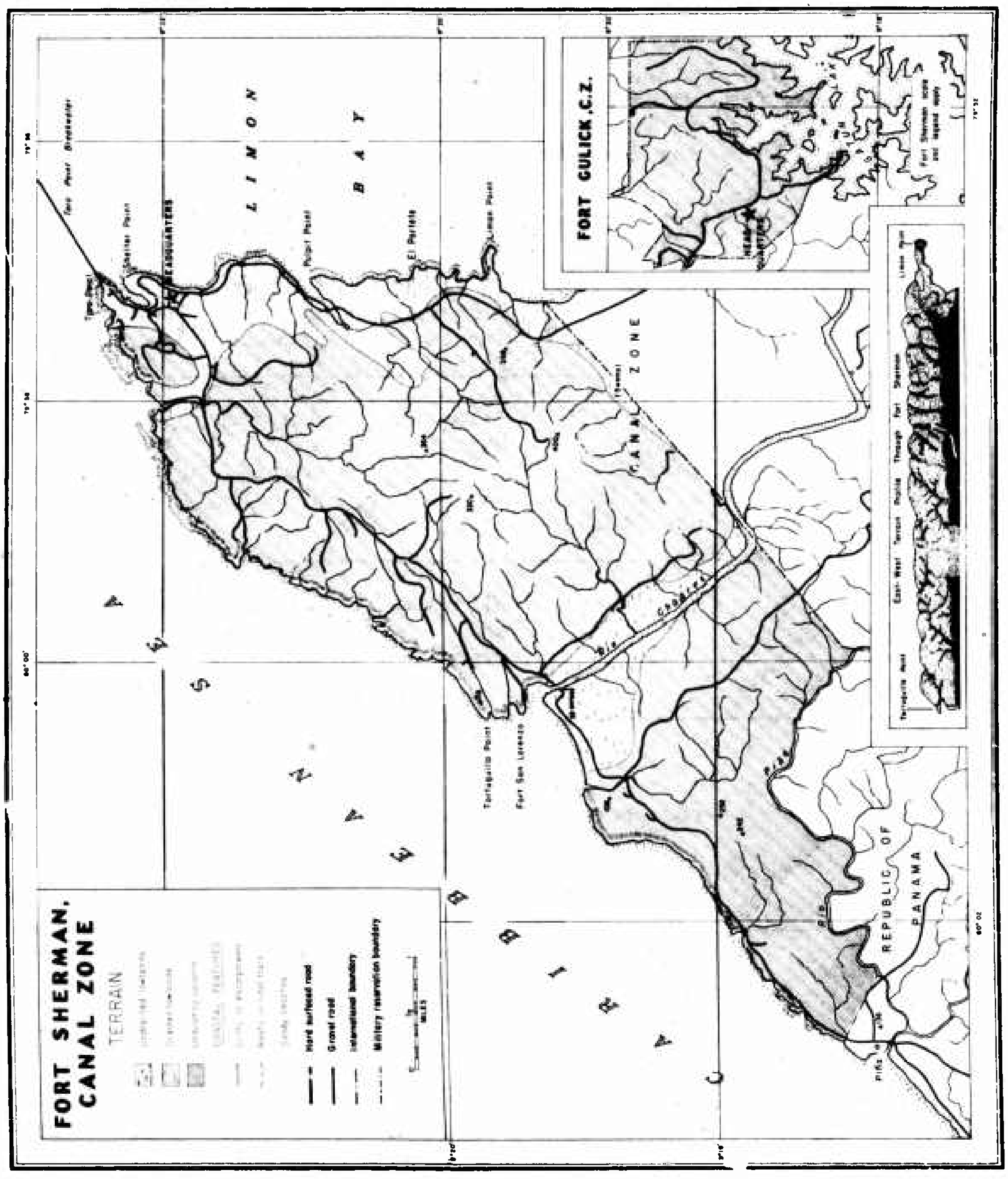
FORT SHERMAN, CANAL ZONE
TERRAIN
FORT GULICK, C.Z.
LIMON BAY
CANAL ZONE
REPUBLIC OF PANAMA

Figure 13

TABLE III: TERRAIN CLASSIFICATION FOR FORT SHERMAN AND FORT GULICK PANAMA CANAL ZONE

Terrain Type	Description	Hydrographic Features	Surface Materials	Vegetation	Remarks
UNDULATING UPLANDS	Maturely dissected hills 50 to 400 ft. in elevation. 15° - 60° slopes. Forested.	Turbulent streams with quick runoff to surrounding lowlands.	Gatun clay derived from underlying limestone.	Tropical evergreen forest.	Section is underlaid by the sandy and fragmental Toro limestone. Forms low bluffs or headlands on the coast.
DRAINED LOWLANDS	Systematically ditched swamp and marsh.	Ditched and channeled for malaria control.	Mottled appearance; if leached properly can be cultivated.	Bush and scrub or various swamp growths.	Extensive along Limon Bay and in scattered areas along the Caribbean.
UNDRAINED LOWLANDS	Salt-water swamp.	Seasonally and/or periodically inundated.	Atlantic muck.	Mangrove and manzanillo.	No distinct delimitations have been made between salt and fresh-water swamps because of periodic flooding, tidal-wind fluctuations and a normally high water table.
	Fresh-water swamp.	(as above)	Alluvium and gravel.	Dense forest.	
	Marsh	(as above)	Atlantic muck.	Grass, reed, and bush.	Marsh includes both salt and fresh-water lands which are permanently saturated. Only slightly above lowtide and flood level, these areas are repeatedly inundated.
COASTAL FRINGE	Sandy beaches	Crescent shaped pockets of varying lengths.	Light to dark sand.	Strand, lined by palms at inner margins.	Many of these beaches are so limited in extent that they are not mapped in this report.
	Escarpment and cliff.	Wave-cut cliffs.	Limestone outcrops.	Palms to dense jungle growth.	Dominates coastline from Toro Point westward to Piña.
	Tidal flats and coral reefs.	Submerged at high tide.	Atlantic muck and coral.	Mangrove and marine.	Mapped as hydrographic features.

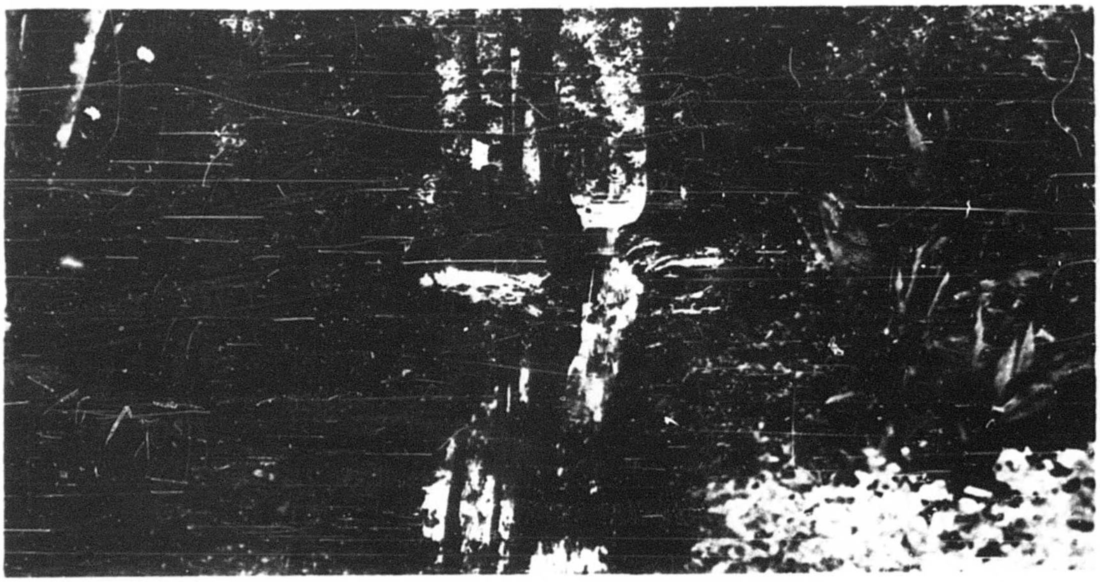

Figure 14: A drainage ditch in the wooded swamp adjacent to Limon Bay. Although many trees of these swamps are rather small, some are almost 100 feet in height.

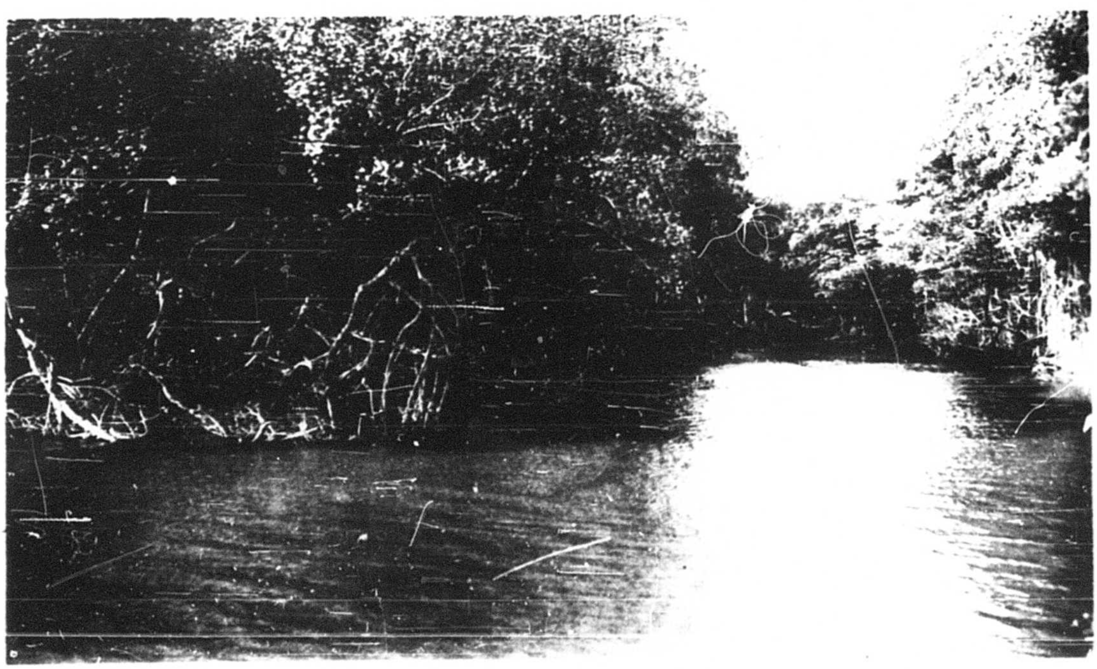

Figure 15: A Mangrove swamp in the Undrained Lowlands. Mangrove swamps line the quiet waters of Limon Bay and much of the Caribbean coast.

Figure 16: The sandy beach near the mouth of the Rio Chagres with tropical evergreen forest immediately adjoining. The rocky headland in the background has only recently been abandoned as a test site.

All of the terrain types described here present considerable obstacles to overland travel. The difficulty of crossing the steep slopes of the Undulating Uplands is increased by the dense growths of vegetation with which they are largely covered. The lowlands also present a problem in trafficability, because of their slippery mud and frequent inundation.

b. Undulating uplands. Most of the Fort Sherman and Fort Gulick Reservations fall within the classification of Undulating Uplands. Rolling hills are prevalent with elevation from 50 to 400 feet (Fig. 3). The characteristic landforms are narrow valleys, steep hillsides, and rounded hilltops where soft rocks are exposed. The hills vary from hogbacks to dome-shaped formations, with small streams exposing hard rocks in steep-sided ravines. Relief ranges from 5 to 10 feet at the Caribbean shore to nearly 400 feet elevation inland from Limon Point.

The principal surface material is Gatun clay, which is derived from the underlying limestone. The material of the mottled substratum is slightly plastic when wet but crumbles on drying. Gatun clay conserves moisture, permitting continued growth of vegetation throughout the dry season; although the surface cracks and bakes slightly, there is always moisture at a slight depth. Drainage is good and there are no indications of serious erosion.

c. Drained lowlands. Lands comprising the Drained Lowland category (Fig. 13) are situated largely along the east coast of Fort Sherman from Toro Point south and are distinguished by the systematic artificial drainage pattern that has been developed to eliminate breeding places for mosquitoes. Excess runoff water is channeled into these drainage canals, and the water level also fluctuates with the ebb and flow of the tide. Thus, these lands are nearly always saturated even though ditched to prevent ponding. The surface materials differ very little from those of the undrained lowlands except that the materials are less water-logged and less plastic.

No distinction has been made between tidal and fresh-water swamps because periodic flooding and tidal fluctuations cause an overlapping of the two types. These areas are slightly above the low-tide level (Fig. 14), and are repeatedly inundated by high tides or wind-impelled waves, even though tidal fluctuations are small.

Around the military posts both the land and its plant covering have been modified by man-made improvements. Extensive low tracts have been cleared and either leveled or filled to provide drill grounds, aviation fields, and bases for other activities; even the remaining swamps have been ditched in order to control mosquitoes. Because of constant spraying and other control methods, mosquitoes, flies, and most other insects have ceased to be a problem. Also, in some areas temporary improvements, such as clearings, ditching for drainage, and gun emplacements, have been made for maneuvers, bivouacs, and testing sites. However, such improved lands comprise only a small portion of the drained lowlands.

d. Undrained lowlands. Most of the undrained lowlands lie along the Rio Chagres (Fig. 15), especially on the left bank near the mouth of the river. There is also a sizable area between the Rio Chagres and Limon Bay, along the southeastern boundary of the Fort Sherman Reservation, although most of the undrained lowlands lie outside of the reservation. As in the case of the drained lowlands, no distinction has been made between salt-water swamps, fresh-water swamps, and marsh. The same factors of seasonal flooding, tidal fluctuations, and a normally high water table make a distinction impractical.

Most of the surface and subsurface material is either alluvium or muck, depending on whether the swamp or marsh is adjacent to a slope or is on a river floodplain. The muck, classified as Atlantic muck, consists of clay, silt, fine sand, and organic material divided into four layers. The lower layer consists of grayish silty clay. A brackish marine layer overlying these lower beds contains abundant mollusk shells in an organic, black silt matrix. This is overlain by swamp deposits composed of partially decayed wood and other vegetable matter intermixed with silt; these deposits are characteristically dark brown to black in color. A surface layer of soft, light gray, plastic clay overlies this organic layer. The muck was deposited upon a stream-eroded topography of considerable relief, and in many places the limestone of the Gatun formation protrudes through the muck in the form of islands. Along the Rio Chagres valley the alluvial deposits of cobbles and pebbles mix locally with the Atlantic muck.

e. Coastal fringe. The low bluffs and headlands, extending along the Caribbean coast from Toro Point southwest to the mouth of the Rio Chagres, are composed of limestone (Fig. 16), which is sandy and fragmental and which grades locally into a "coquina" or shell marl. At the base of the bluffs are extensive tidal flats or reefs. The cliffs, wavecut from comparatively soft limestone, are steep and in some places vertical. The shoreline is interrupted by small coves, with a very narrow beach at the head of each cove and a deep ravine extending inland.

From Toro Point southward along Limon Bay the coastline is paralleled by coral formation of varying widths. Sandy beaches are rare along this coast, and man-made causeways have considerably altered the shoreline.

4. Vegetation

a. General. The vegetation of the Atlantic Sector consists primarily of tropical evergreen forest on the undulating uplands and some form of marsh plants or swamp forest in the lowlands (Table IV).

TABLE IV: VEGETATION CLASSIFICATION FOR FORT SHERMAN AND FORT GULICK, PANAMA CANAL ZONE

General Type	Habitat	Vegetation	Remarks
Lowland Marsh and Swamp Forest	Coastal Fringe, Undrained Low-land, Drained Lowlands	Sago Palm, Mangrove, Cativo, Heliconia, Manzanillo, Sedge, Sawgrass, Giant Papyrus, Wild Cane, Arrowhead, Smart-weed	Mangrove and other halophytic plants dominate. Vege-tative composition varies, and patches of swamp forest are interspersed with marsh. The small, poisonous manzanillo bush is abundant throughout.
Tropical Evergreen Forest	Coastal Fringe, Undulating Up-lands	Coconut, Manicaria, and Corozo Palms; Breadfruit,Madrono, Papaya, Banana, Nispero, Star-apple, Cabbagebark, Zapote, Sandbox, Tonka, Wild Fig, Lianas	Tropical evergreen forest extends to edge of the escarp-ment and into many small coves along the coasts. Dense undergrowth and vines are prevalent. Tree crowns may be in several tiers, with the tallest over 100 feet high.
Clearings and As-sociated Vegetation	Temporary and Permanent In-stallations	Lawn grass, Coco-nut palm, Balsa, Citrus Fruits, Ornamental Shrubs and Flowers	Cleared areas around residences, troop housing, and post facilities. Fallow fields and abandon-ed clearings are subject to almost immediate regrowth by secondary vege-tation.

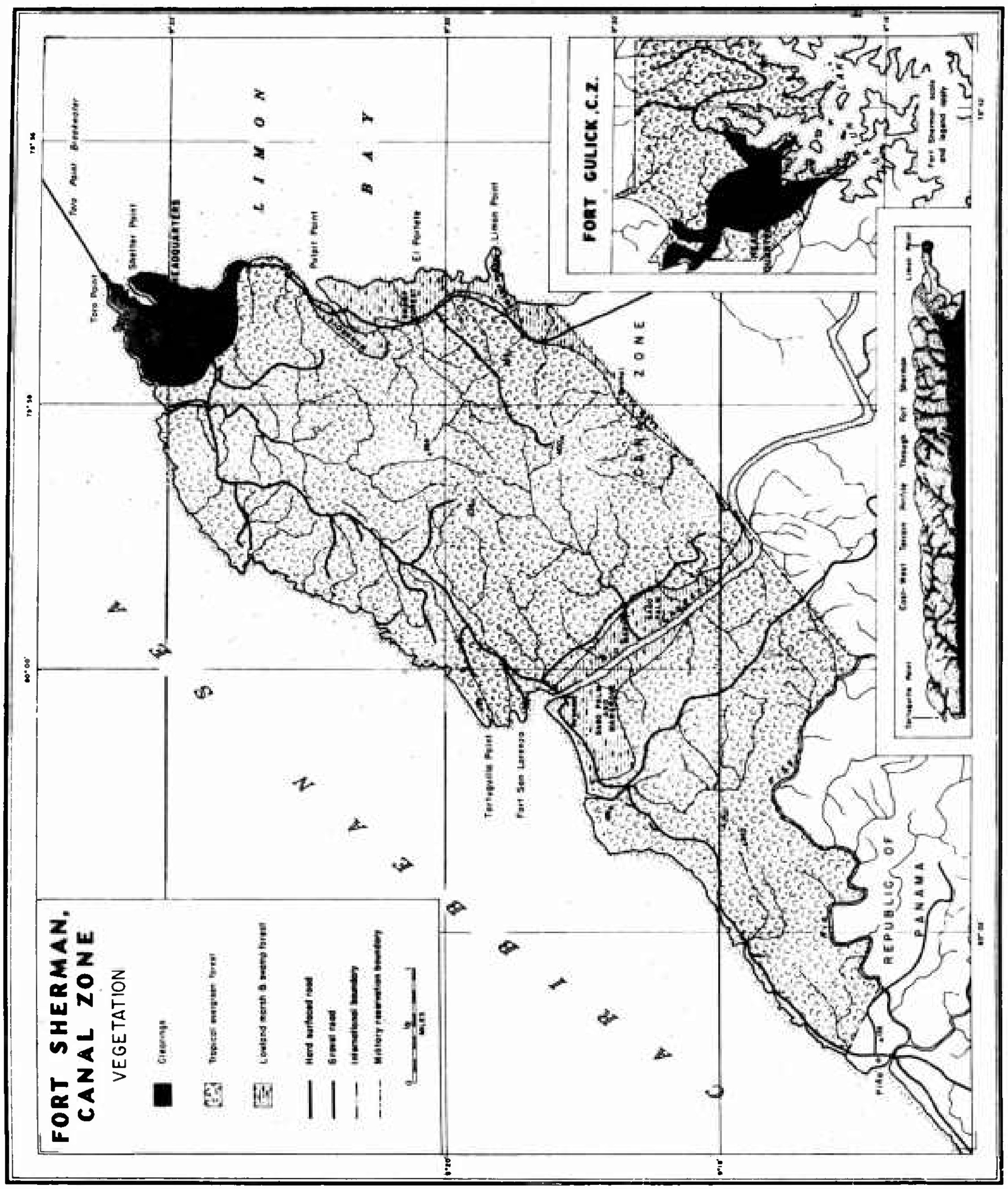
FORT SHERMAN, CANAL ZONE
VEGETATION
Clearings
Tropical evergreen forest
Lowland marsh & swamp forest
Hard surfaced road
Gravel road
International boundary
Military reservation boundary
MILES
FORT GULICK, C.Z.
LIMON BAY
CANAL ZONE
REPUBLIC OF PANAMA
HEADQUARTERS
Toro Point
Shelter Point
Limon Point
Tortuguilla Point
Fort San Lorenzo

Figure 17

There is little difference between the vegetation of the drained and undrained lowlands. However, a number of different plant associations are found in different parts of these areas and where possible they have been designated on the Vegetation Map (Fig. 17). Vegetation shows little change from one month to another; the trees and herbs are green throughout the year. Very few of the trees shed their leaves seasonally, but there are a few that do.

Construction of the canal and the military posts in the Panama Canal Zone has had a considerable effect upon the plant life in the area. The virgin forests were almost entirely destroyed by cutting timber for lumber and charcoal, and by leveling, filling, and ditching activities in the more settled areas. However, in this climate the vegetation returns rapidly; land now covered with what appears to be untouched forest may have been under cultivation at one time. The vegetation is dense and in most places impenetrable without the use of a machete.

b. <u>Lowland marsh and swamp forest</u>. A large proportion of the inundated lowlands of Fort Sherman, both drained and undrained, has vegetation that may be designated either salt-water swamp, fresh-water swamp, marsh, or some combination of the three. Pure stands in any of these categories are rare. The mangrove thickets (Fig.15) are easy to define and occur in both salt-water and fresh-water swamps, though the species are different. There is a vegetative transition zone where salt water meets and periodically mixes with fresh water.

Open salt marsh or meadow appears only along the right bank of the Rio Chagres about midway through the Fort Sherman Reservation, and covers a very small acreage. However, there are extensive areas of marsh meadow south of Fort Sherman near Gatun. Much of the grass is head-high or higher, and occasionally cane brakes rise to 20 feet.

The sago palm, bordering the mangrove thickets and swamp forests, is a prominent feature of the vegetation along Fort Sherman's south-eastern boundary and on both banks of the Rio Chagres. This palm grows successfully on gently sloping saturated ground and forms a transition between the swamp forests and the tropical evergreen forests on the lower slopes.

The swamp forests along the shores of Limon Bay have extremely dense canopies, shading the ground to such an extent that it is difficult to take photographs with natural light. The forest for the most part is well developed but the trees are not as tall as those of the hillsides, and fewer species are represented.

c. <u>Tropical evergreen forest</u>. Most of the area is covered with tropical evergreen forest, which is predominantly secondary growth.

There is a large variety of species, and pure stands of a species cannot be found. A number of the trees rise to heights of 100 feet or more on the rolling, well-drained land. Many of the trees are so tall that it is difficult to identify them except in the case of a few with distinctive foliage. Lower trees find space for expansion beneath the taller ones and form indistinct tiers of vegetation. Trees 125 feet or more in height are comparatively few in number and stand in sharp contrast to an upper forest canopy which averages 80 feet in height. A lower tier of trees averages 40 to 60 feet in height beneath the upper forest canopy (Fig. 18), while the third and lowest layer averages 20 to 30 feet. The forest understory is composed of thickets and shrubs, some of which are 10 to 15 feet high, ranging from relatively sparse growths to dense thickets. The herbaceous vegetation of the forest floor is relatively unimportant. However, the lianas, or coarse woody vines, offer a serious impediment to travel.

The tropical evergreen forest is present throughout the undulating uplands, covering the steepest hills and in many places extending coastward to the water's edge. Islands of upland, such as the tip of Limon Point, are covered with prolific vegetation. Where the shoreline rises gradually, the palms and mangrove thickets of the coast give way to evergreen forest when soil conditions permit. The waters of Gatun Lake at Fort Gulick border on forested slopes which extend to the lake shore, with none of the lowland swamp types present.

d. <u>Clearings and associated vegetation.</u> Temporary clearings and fields left fallow soon develop dense growths of scrub and coarse weedy shrubs and herbs. Examples of such fields are seen at abandoned firing ranges, old test sites (Figs. 12 and 19), and other locations once cleared for use and later abandoned.

The course of succession on old clearings begins with grasses, abundant sedges and a variety of broad-leaved herbs. However, most of these pioneers are short-lived. Plants such as the heliconias and the panama-hat palm appear after a year, together with numerous seedlings of the trees which will dominate later. Also, lianas become established, making this vegetation an impenetrable tangle. Trees become dominant after two years, forming a young secondary forest. Additional species enter, and the vegetation takes on the aspect of the tropical evergreen forest. In succeeding years this vegetation is more dense and more difficult to penetrate than the primary forest, until the undergrowth and smaller trees are shaded out at a still later stage.

There are close-cropped lawns, clipped shrubbery, and well-tended trees around permanent installations. Natural growths of vegetation remain in inaccessible gullies or along steep slopes. Around the regularly tended grounds, there is a transitional zone of scrubby marginal growths where the vegetation is subject to clearing in alternate years or at infrequent intervals.

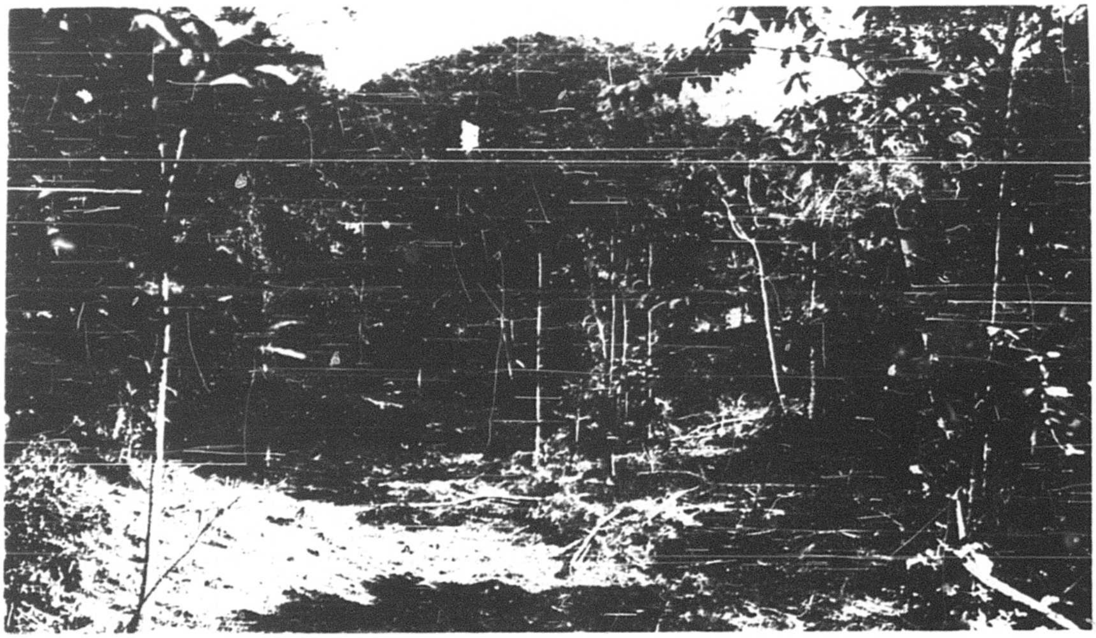

Figure 18: A typical upper forest canopy.

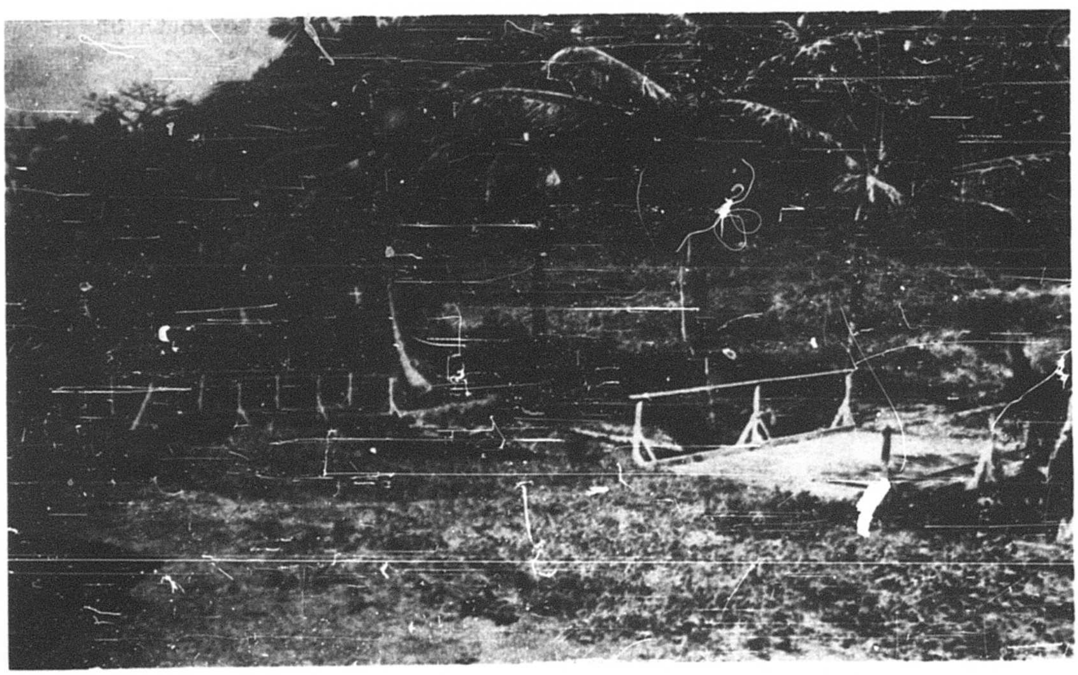

Figure 19: Recent test site used by the Quartermaster Corps on the Fort Sherman Reservation.

5. Summary

The Fort Sherman and Fort Gulick Military Reservations are among the most favorable areas for tropical testing under the political jurisdiction of the United States. The climate is predominately marine, with no large variation in temperatures. The average monthly temperatures are near 80°F; throughout the year less than three percent of the days have temperatures above 90°F or below 70°F. The average annual precipitation is about 130 inches, of which nine-tenths falls during the eight-month period from May through December. The mean relative humidity for this period exceeds 82 percent every month. The northeast trade winds blow steadily during the relatively dry season from January through April. The average monthly rainfall is 1.5 inches in February and March, contrasting with 22 inches in November, the wettest month.

The terrain varies from flat, low-lying inundated swamplands to low hills with elevations of 50 to 400 feet. The hills have rounded tops, steep slopes, and narrow valleys. These hills comprise approximately four-fifths of the area of Fort Sherman and all of Fort Gulick. Alluvial plains constitute the remaining portion of Fort Sherman. The coastal portion of the Fort Sherman Reservation, extending from Toro Point to the mouth of the Rio Piña, is characterized by coral formations and a series of low, steep cliffs, interspersed with sandy beaches southwest of the mouth of the Rio Chagres.

A tropical evergreen forest with a great variety of species dominates the vegetation in the upland areas. Mangrove swamps border the coast and extend up the Rio Chagres as far as Gatun, the inland limit of tidal penetration. Various marsh plants cover the rest of the lowlands and the frequently flooded areas.

6. Acknowledgments

Acknowledgments are made to personnel of USARCARIB, the Naval Research Laboratory, and the Panama Canal Company for their cooperation. The graphs and maps were drafted by Gertrude Barry, Ann Richmond, Elizabeth Mason, Odette Taft, and Donald Cox.

7. References, Aerial Photography, and Map Coverage.

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b. <u>Aerial photographic coverage</u>

AAF; 1945; 1:5,000; Mission 5-M1 (Port approach to Atlantic or North Entrance).

AAF; 1947; 1:20,000; Mission M-51 (Complete coverage of Fort Sherman Reservation).

AAF 91st Reconnaissance Squadron; Sept. 5, 1947 and Oct. 8, 1948; 1:5,000 (Starboard approach to Atlantic or North Entrance).

__________ 1951; 1:5,000 (Uncontrolled mosaic prepared by 7465th S. U. - Engineer Reproduction - U. S. Army, AMS, Corozal, Canal Zone).

Private contractor for Army Corps of Engineers; 1951, 1952, and 1953; 1:5,000 and 1:20,000 (Two percent of contract area had been photographed as of January 1953).

c. <u>Map coverage</u>.

U. S. Army Corps of Engineers, Terrain Map Series, 1:20,000.

Army Map Service, Series E761, 1:50,000.

APPENDIX A

CLIMATIC DATA
CRISTOBAL, CANAL ZONE

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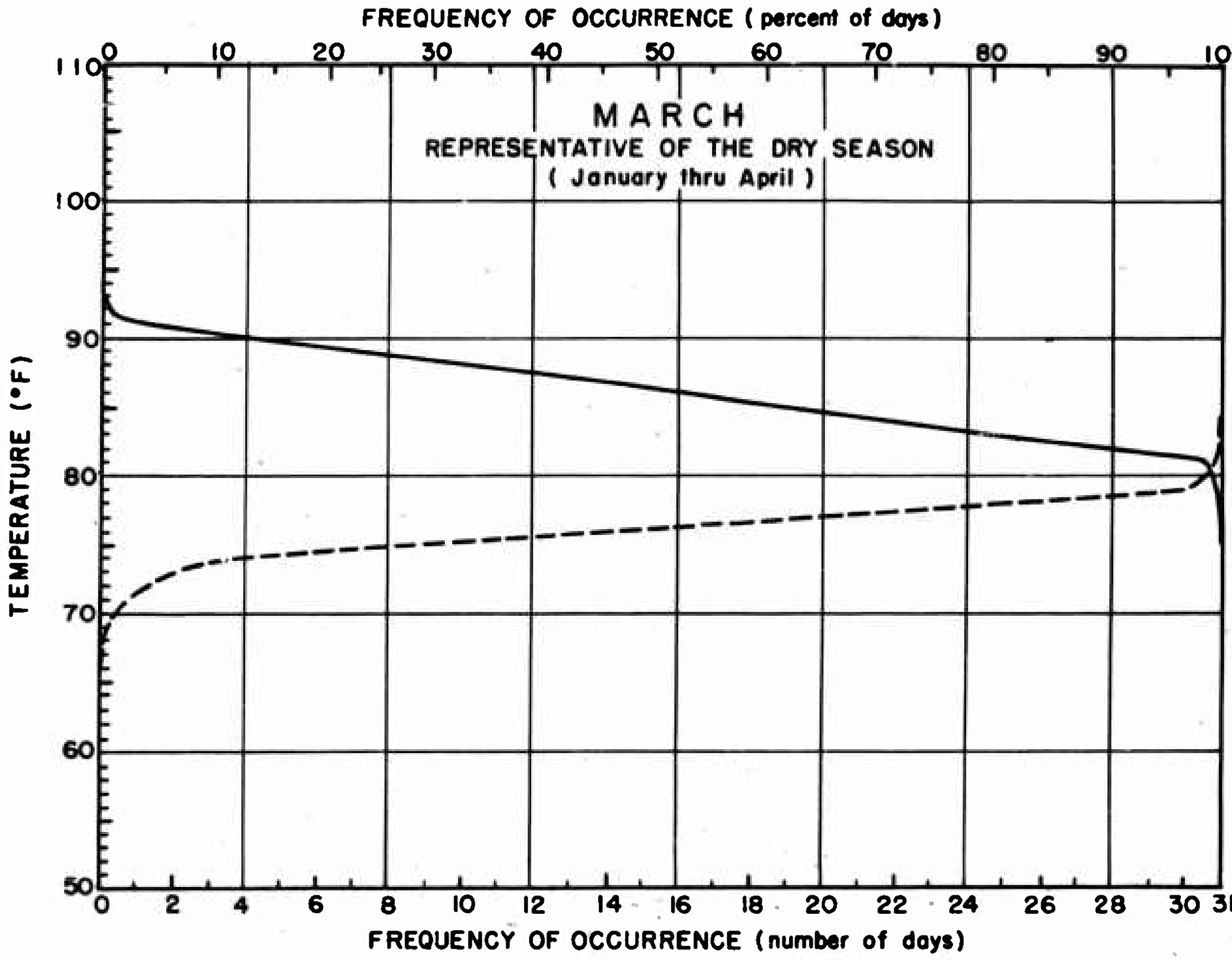
Percentage occurrence of wind speeds by groups	49

*At Fort Sherman Test Site

EXTREME TEMPERATURE FREQUENCIES

CRISTOBAL, CANAL ZONE

(Length of Record: 20 years)



—— Number of days (or percent of days) with daily maximum temperature equal to or greater than given temperatures

– – Number of days (or percent of days) with daily minimum temperature equal to or less than given temperatures

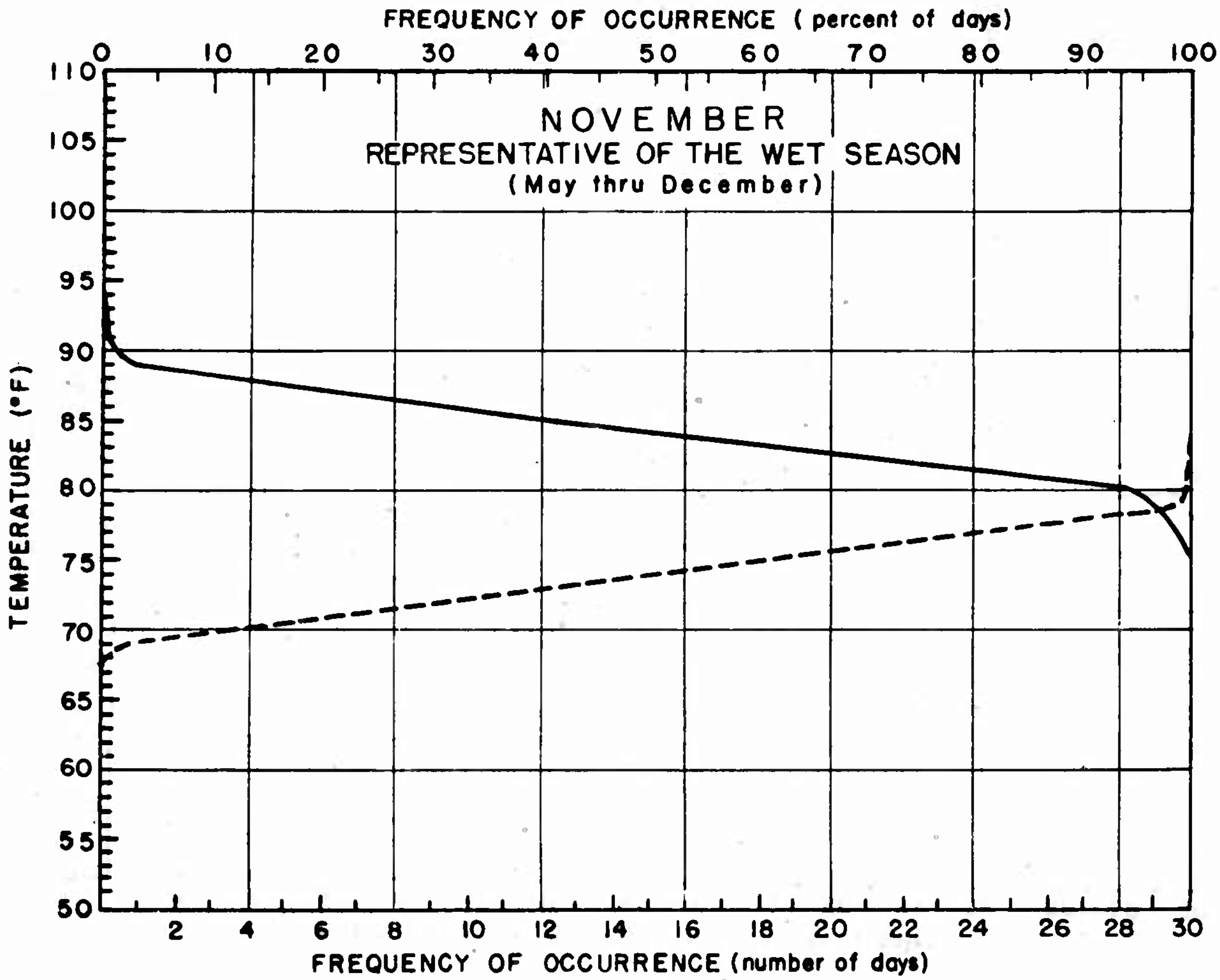
Example: A maximum temperature of 86°F or greater may be expected 16 days during March.

Figure 20

EXTREME TEMPERATURE FREQUENCIES

CRISTOBAL, CANAL ZONE

(Length of Record: 20 years)



—— Number of days (or percent of days) with daily maximum temperature equal to or greater than given temperatures.

– – Number of days (or percent of days) with daily minimum temperature equal to or less than given temperatures.

Example: A maximum temperature of 86°F or greater may be expected 10 days during November.

Figure 21

AVERAGE DAILY MARCH OF RELATIVE HUMIDITY
CRISTOBAL, CANAL ZONE
(Length of Record: 20 years)

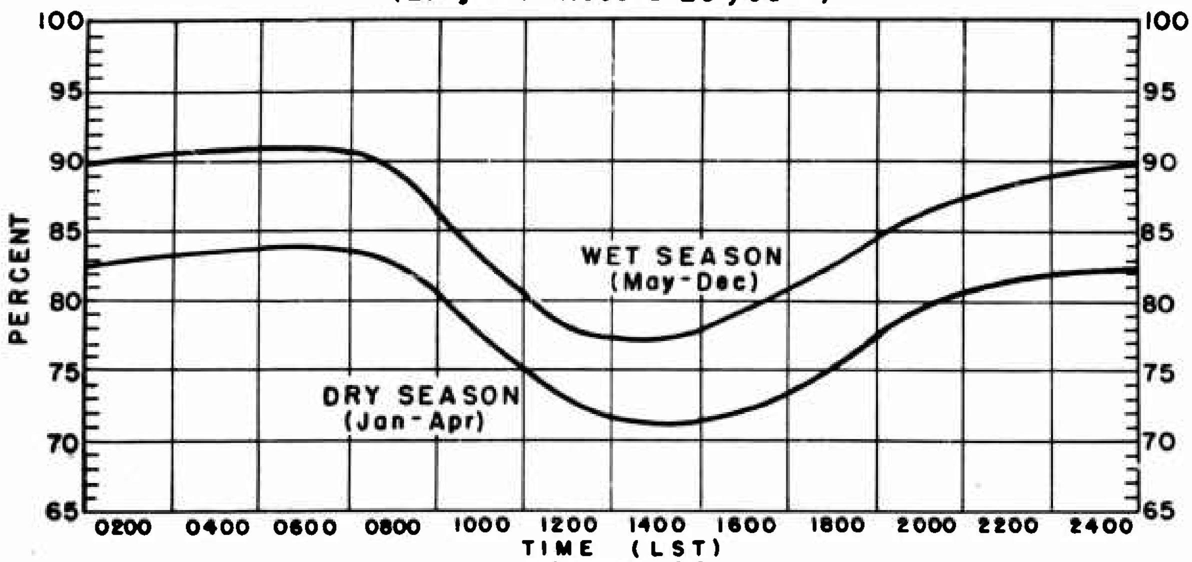


Figure 22

AVERAGE DAILY MARCH OF TEMPERATURE
CRISTOBAL, CANAL ZONE
(Length of Record: 20 years)

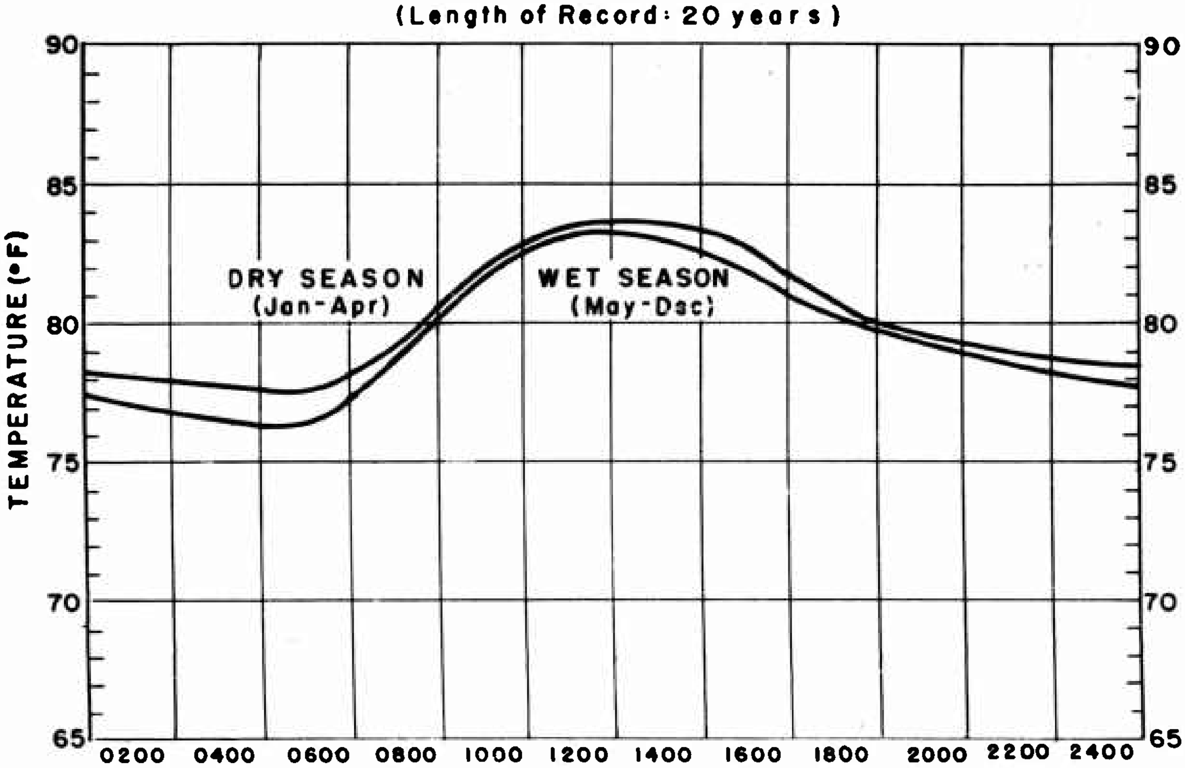


Figure 23

PRECIPITATION REGIME
CRISTOBAL, CANAL ZONE
(Length of Record: 73 years)

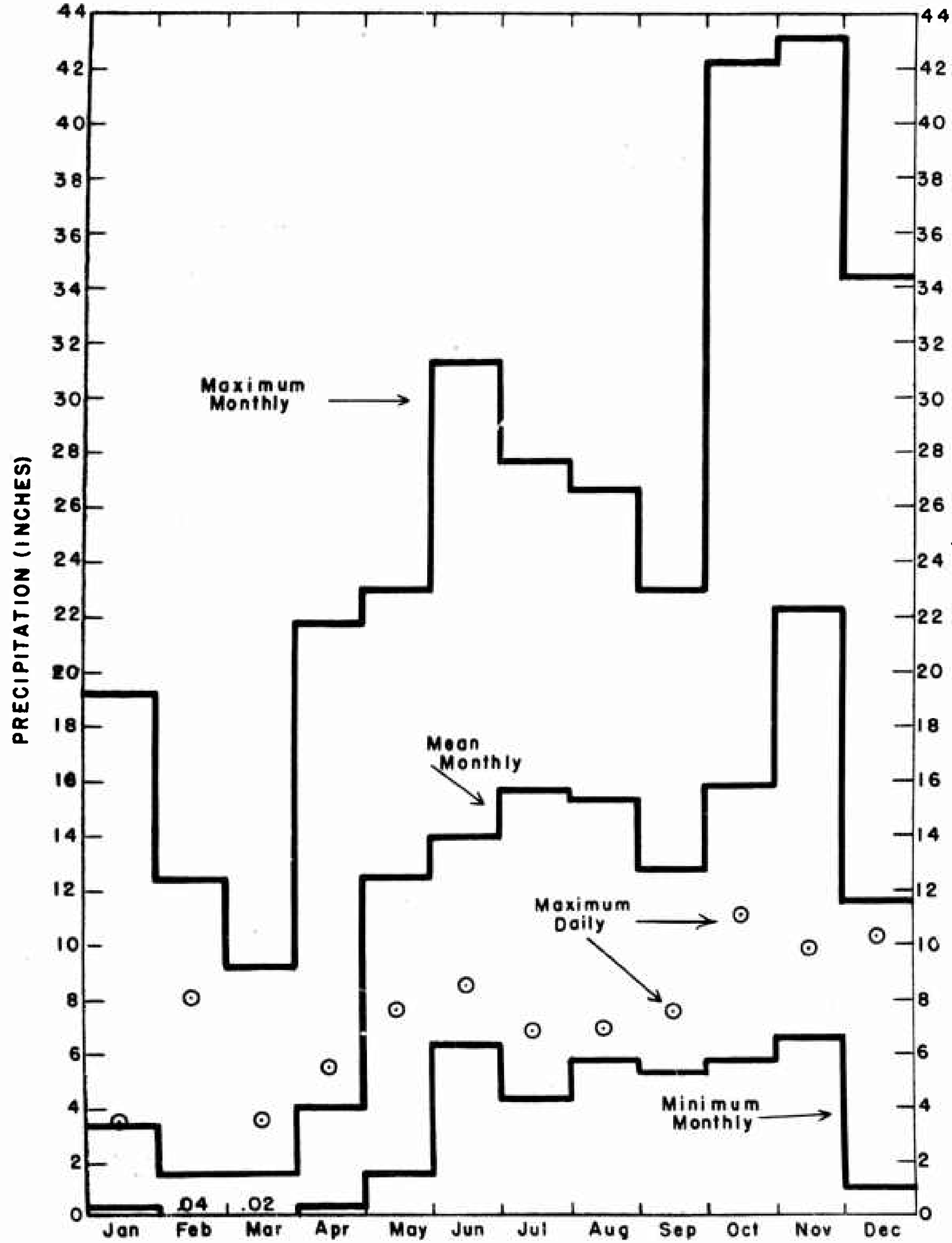
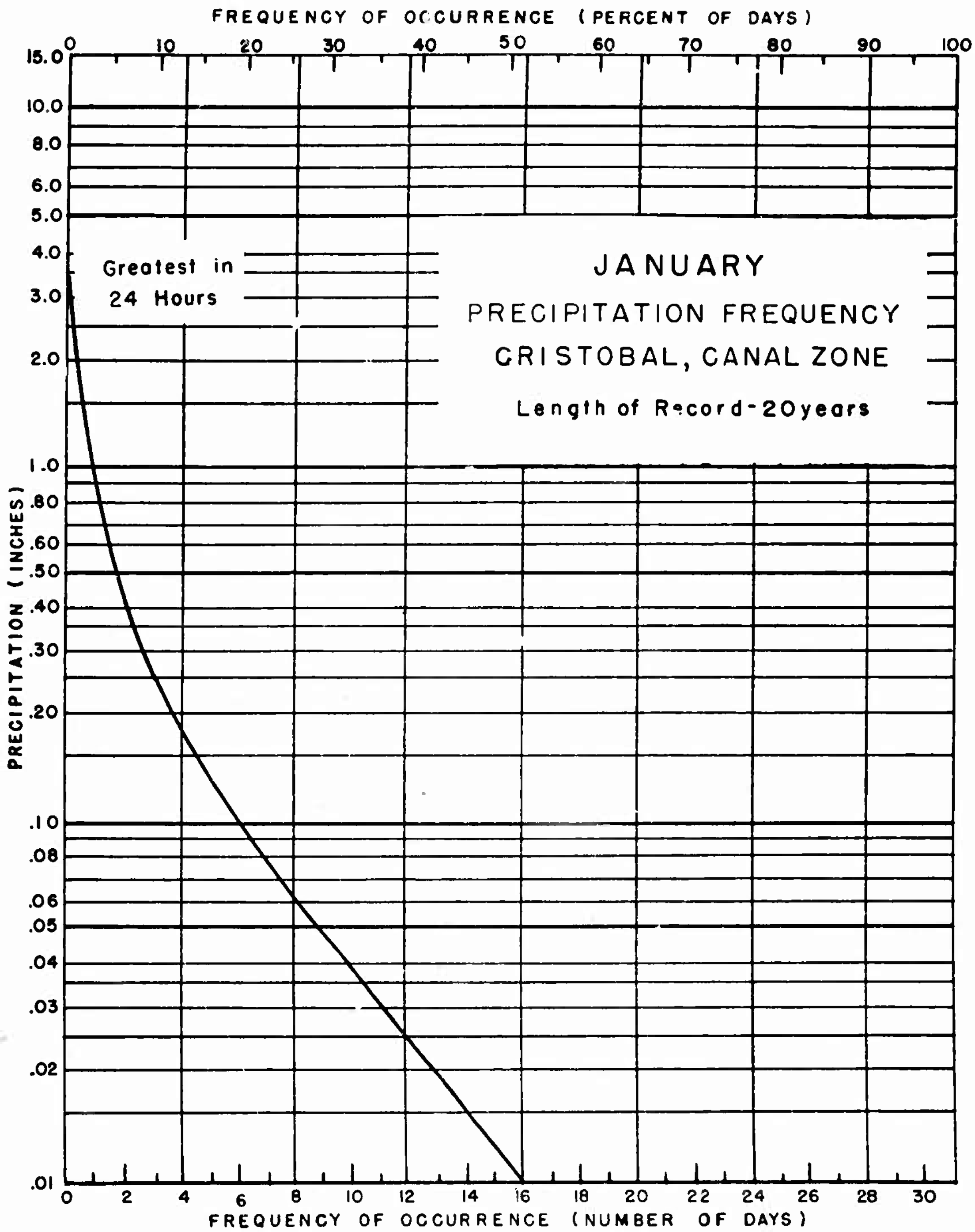


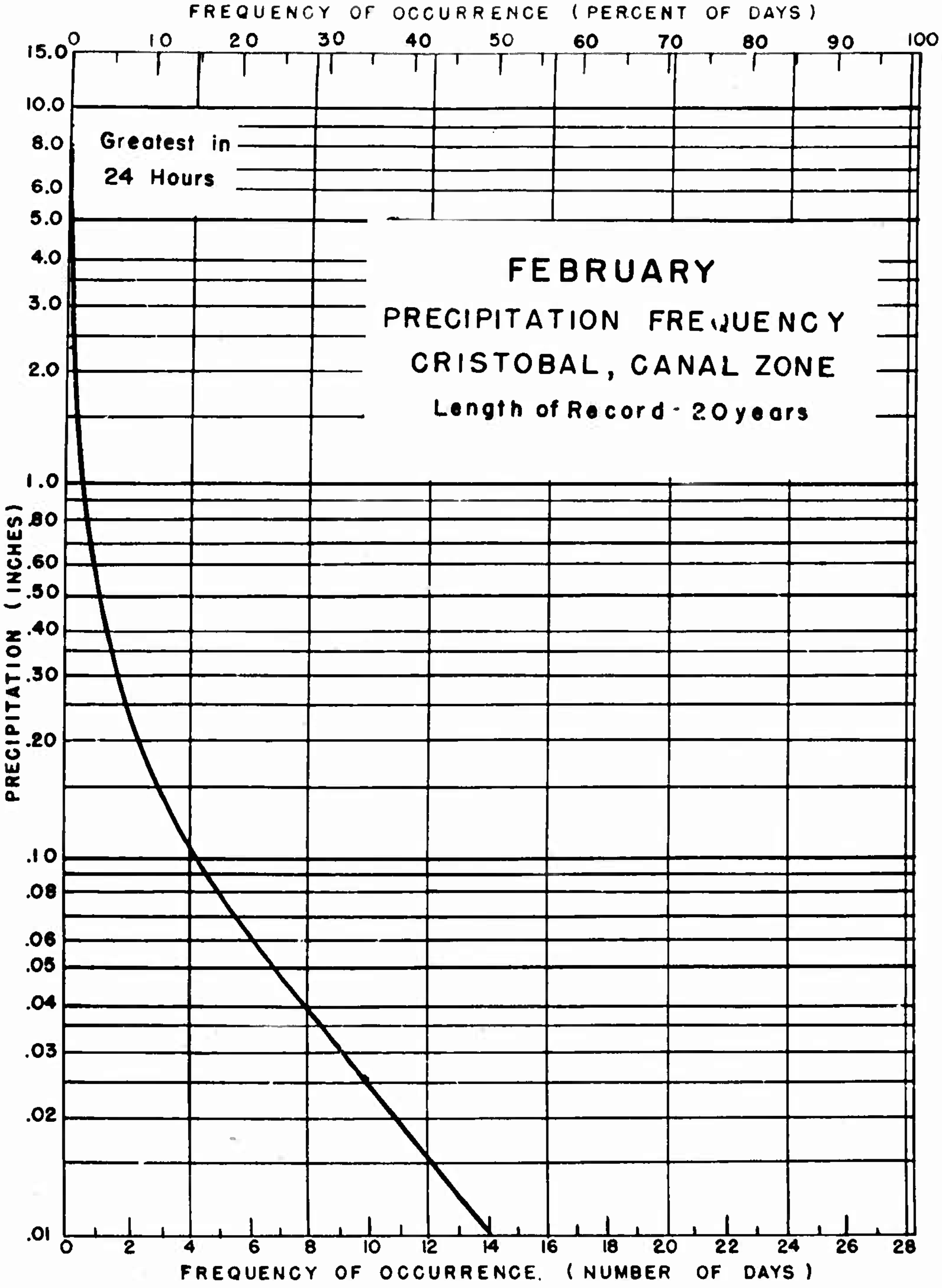
Figure 24



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.05 inches or more precipitation may be expected to occur 9 days during January (or approximately 29 percent of the days).

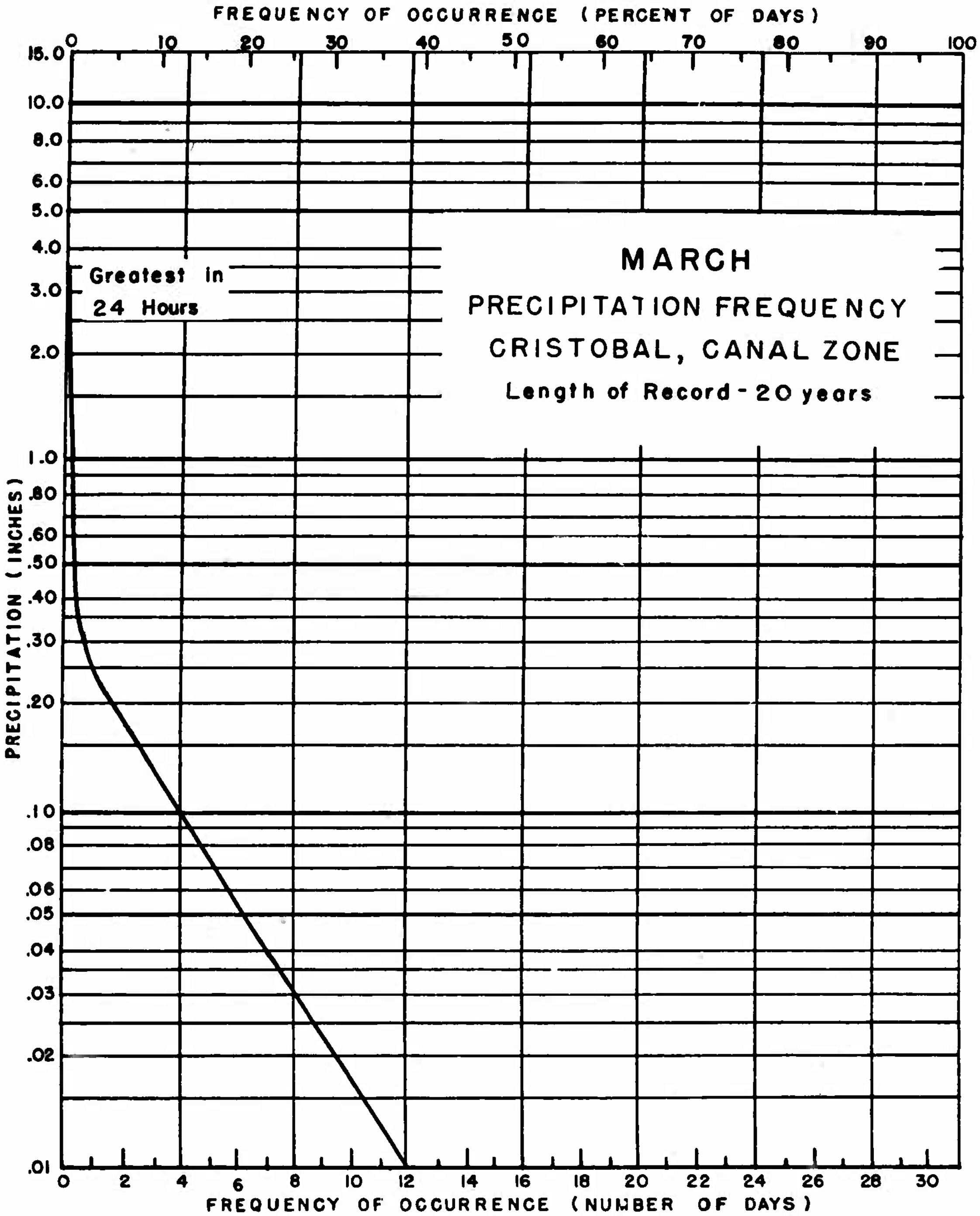
Figure 25



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.04 inches or more precipitation may be expected to occur 8 days during February (or approximately 28 percent of the days).

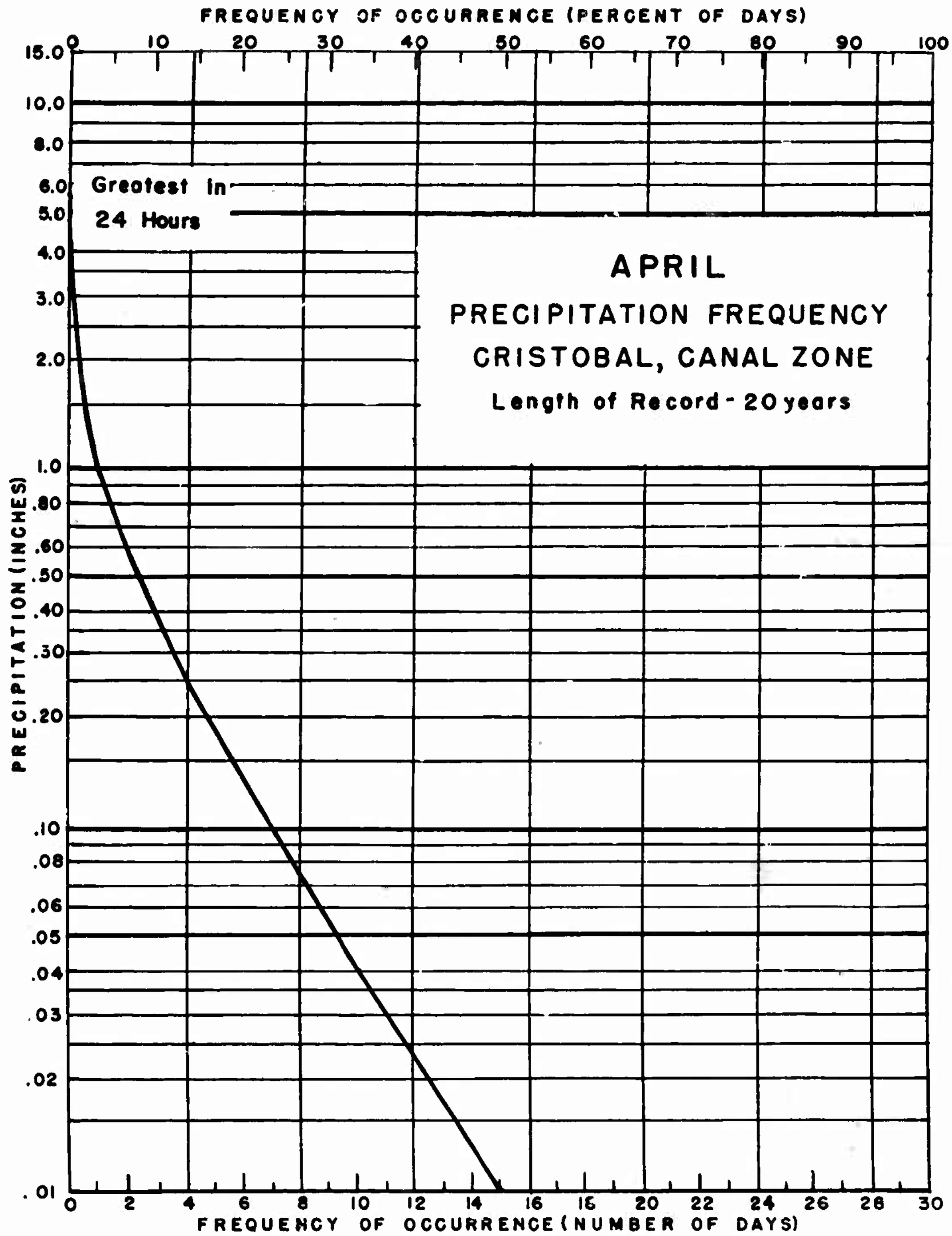
Figure 26



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.03 inches or more precipitation may be expected to occur 8 days during March (or approximately 26 percent of the days).

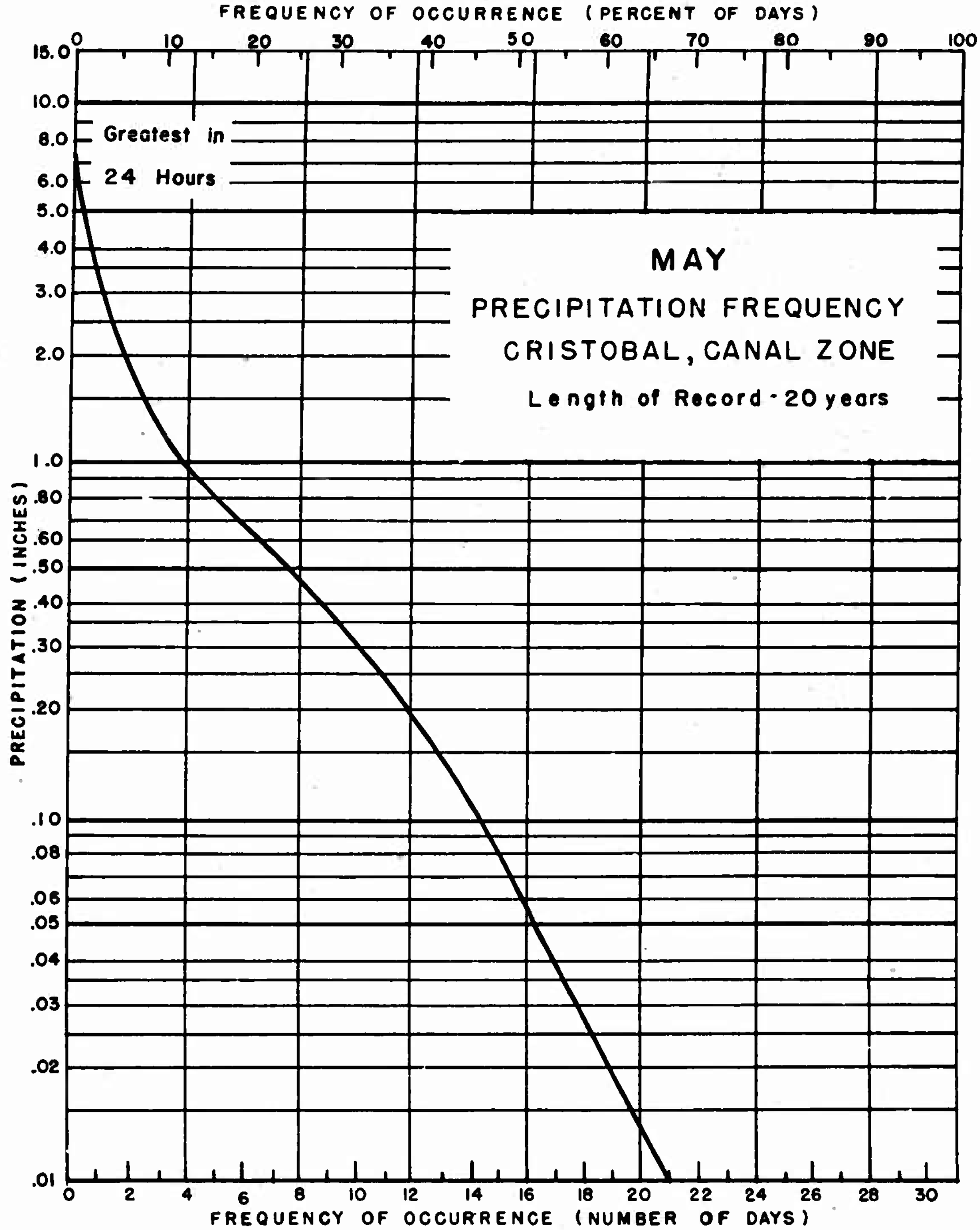
Figure 27



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.10 inches or more precipitation may be expected to occur 7 days during April (or approximately 23 percent of the days).

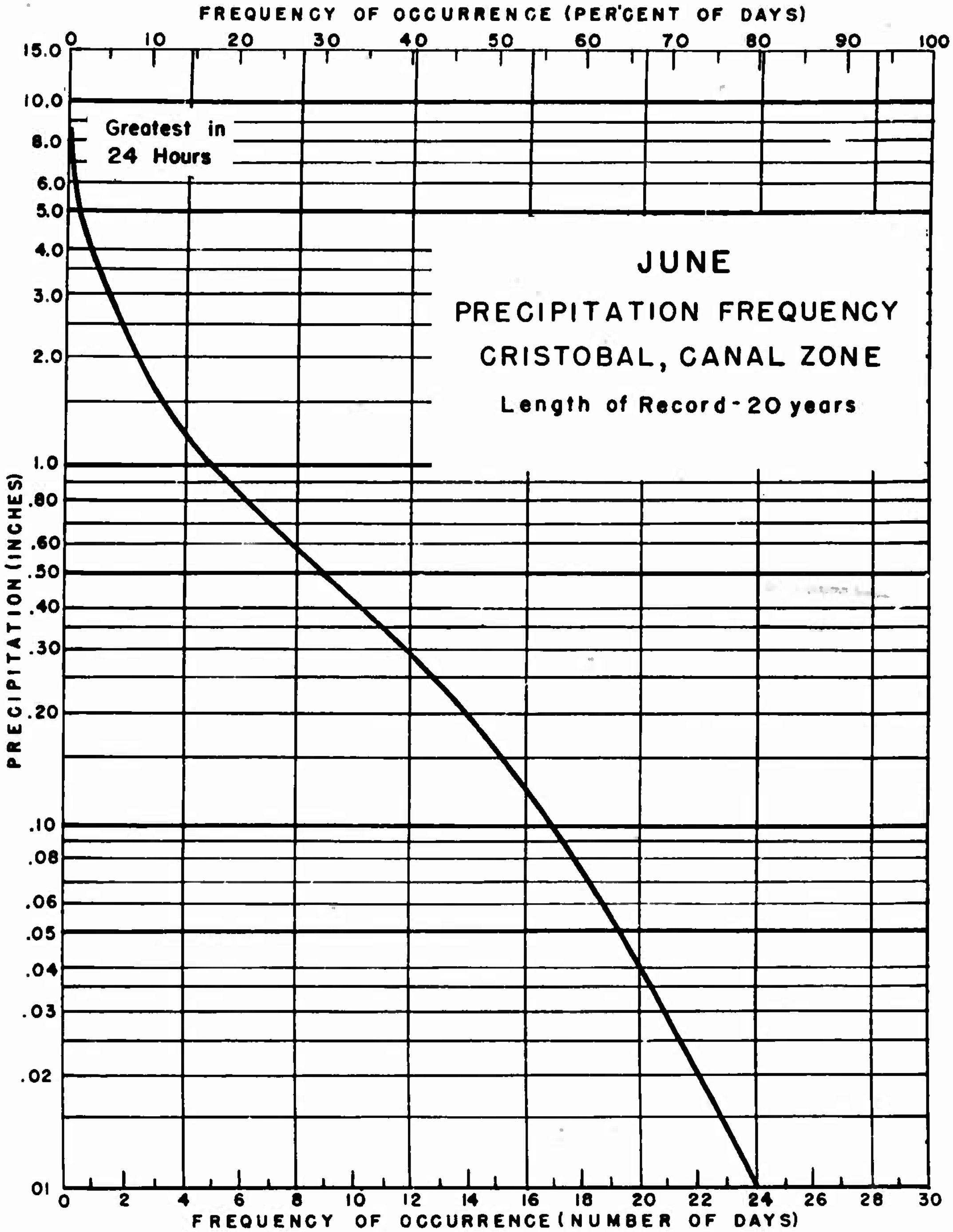
Figure 28



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.20 inches or more precipitation may be expected to occur 12 days during May (or approximately 39 percent of the days).

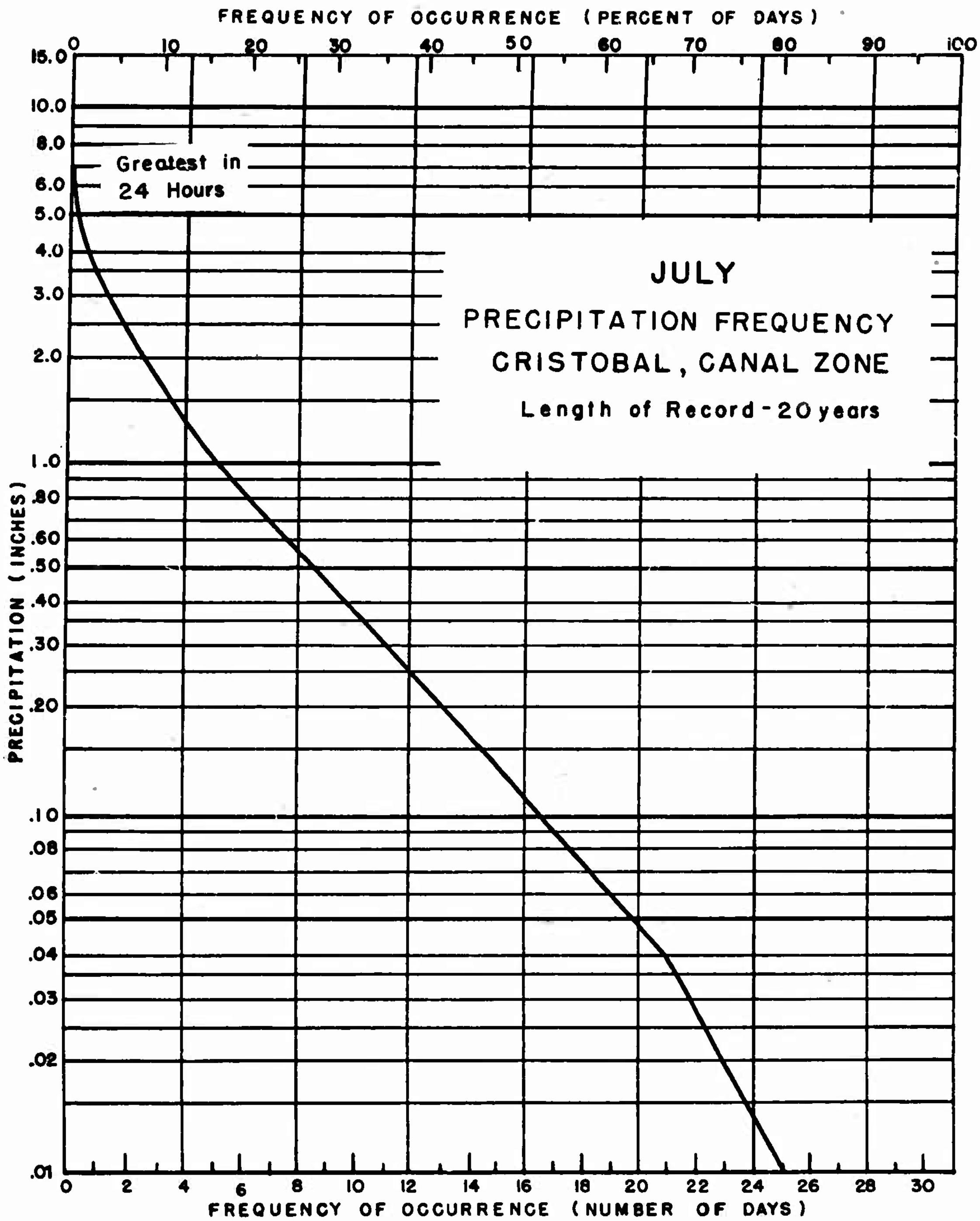
Figure 29



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.50 inches or more precipitation may be expected to occur 9 days during June (or approximately 30 percent of the days).

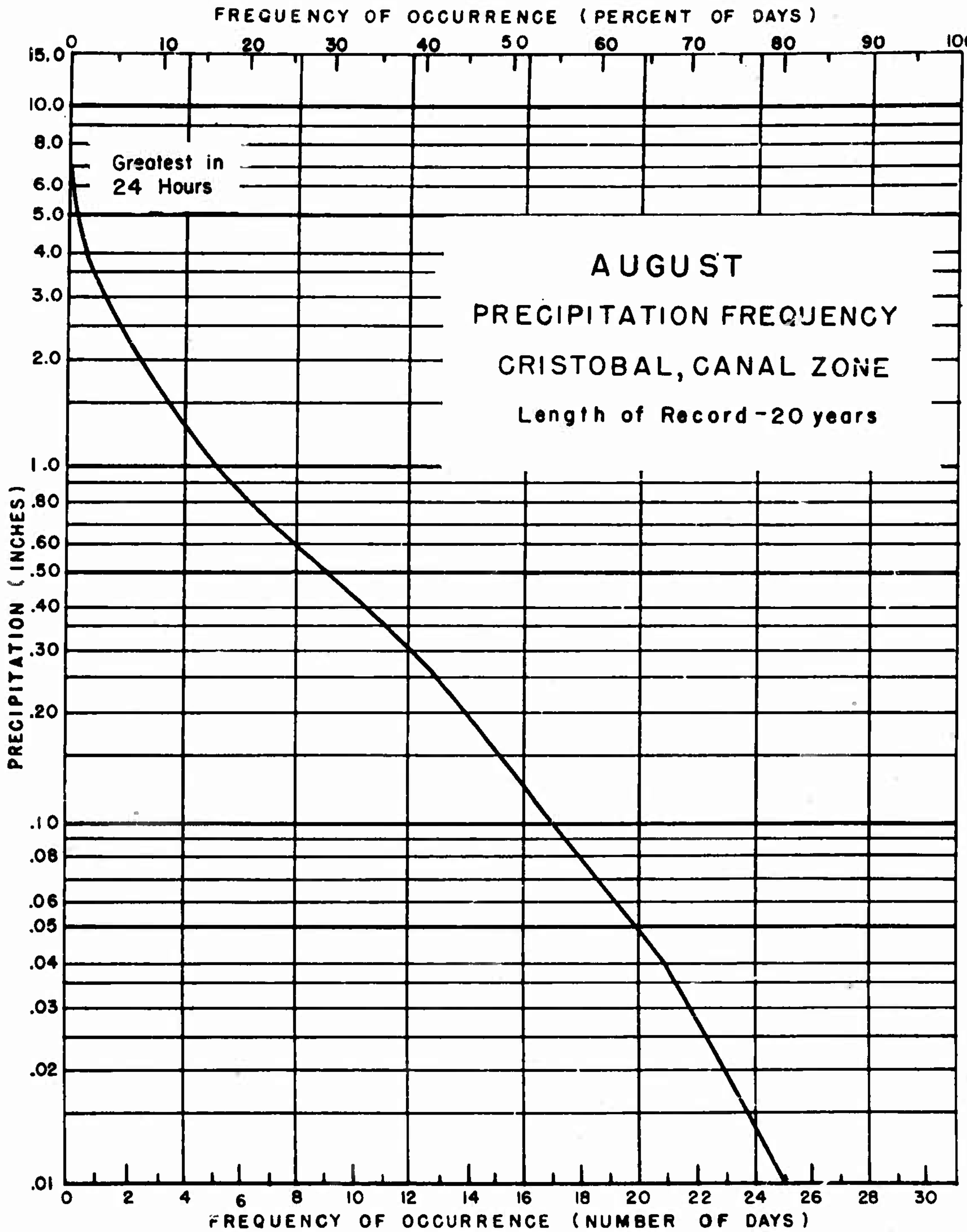
Figure 30



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.70 inches or more precipitation may be expected to occur 7 days during July (or approximately 23 percent of the days).

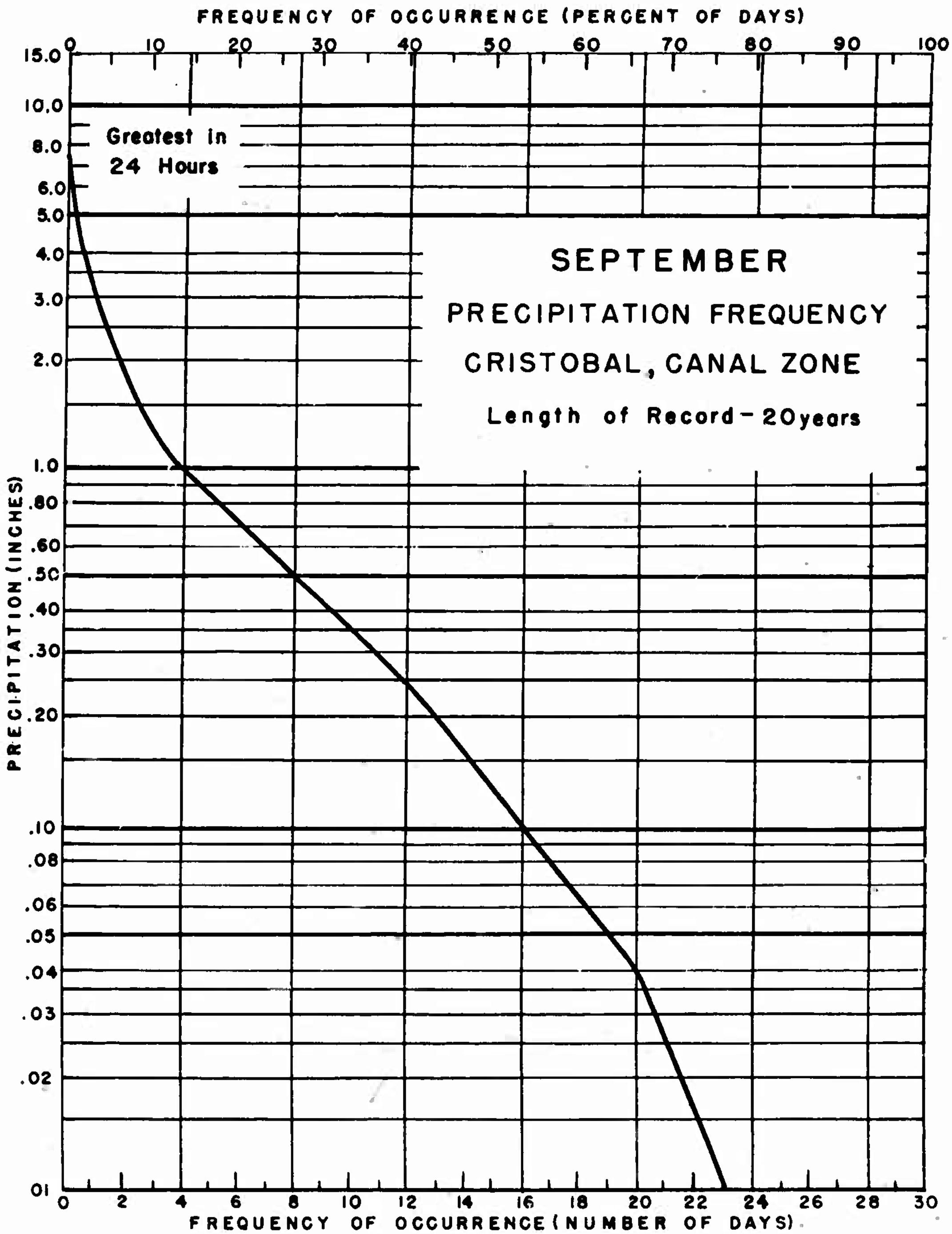
Figure 31



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.60 inches or more precipitation may be expected to occur 8 days during August (or approximately 26 percent of the days).

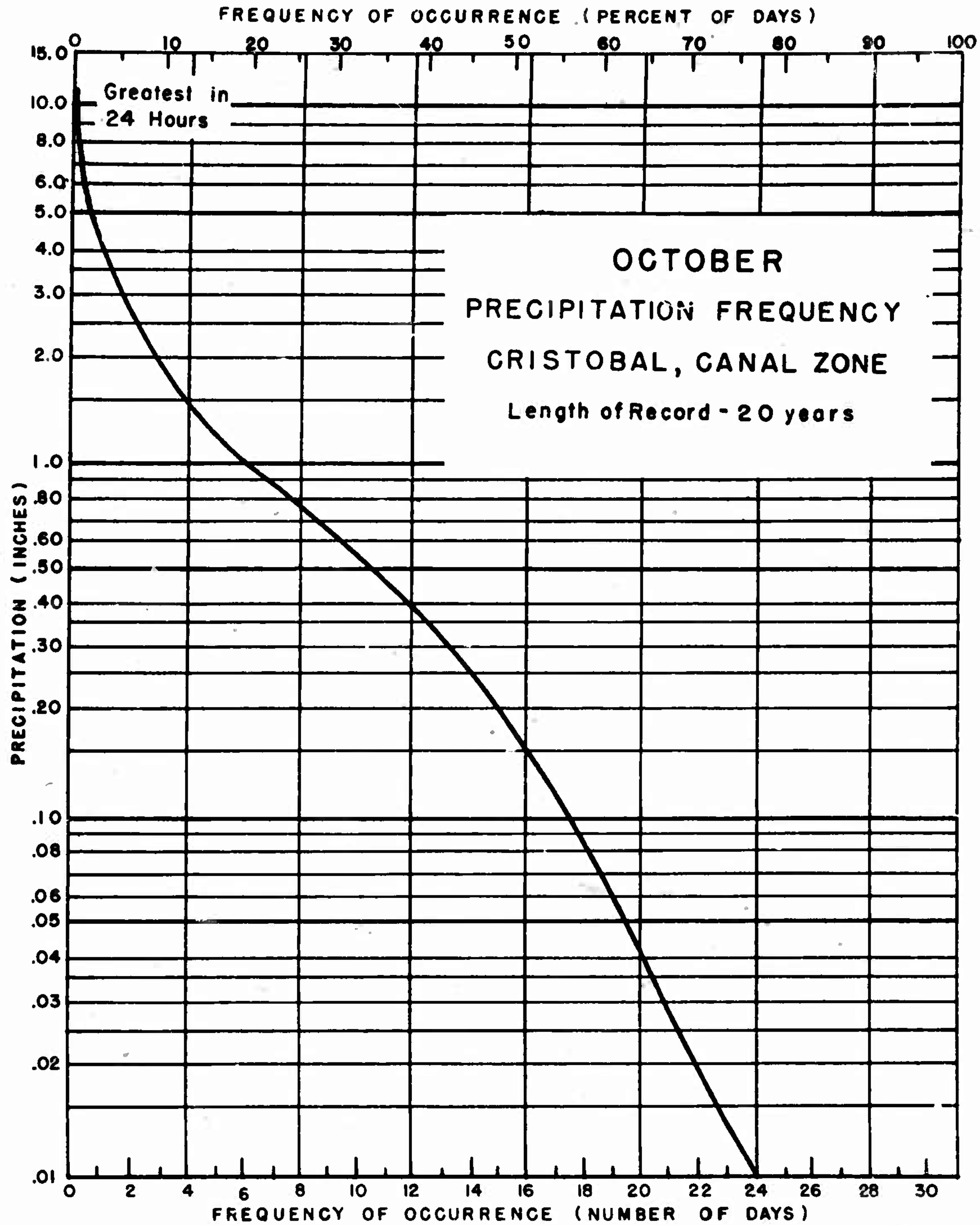
Figure 32



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.50 inches or more precipitation may be expected to occur 8 days during September (or approximately 27 percent of the days).

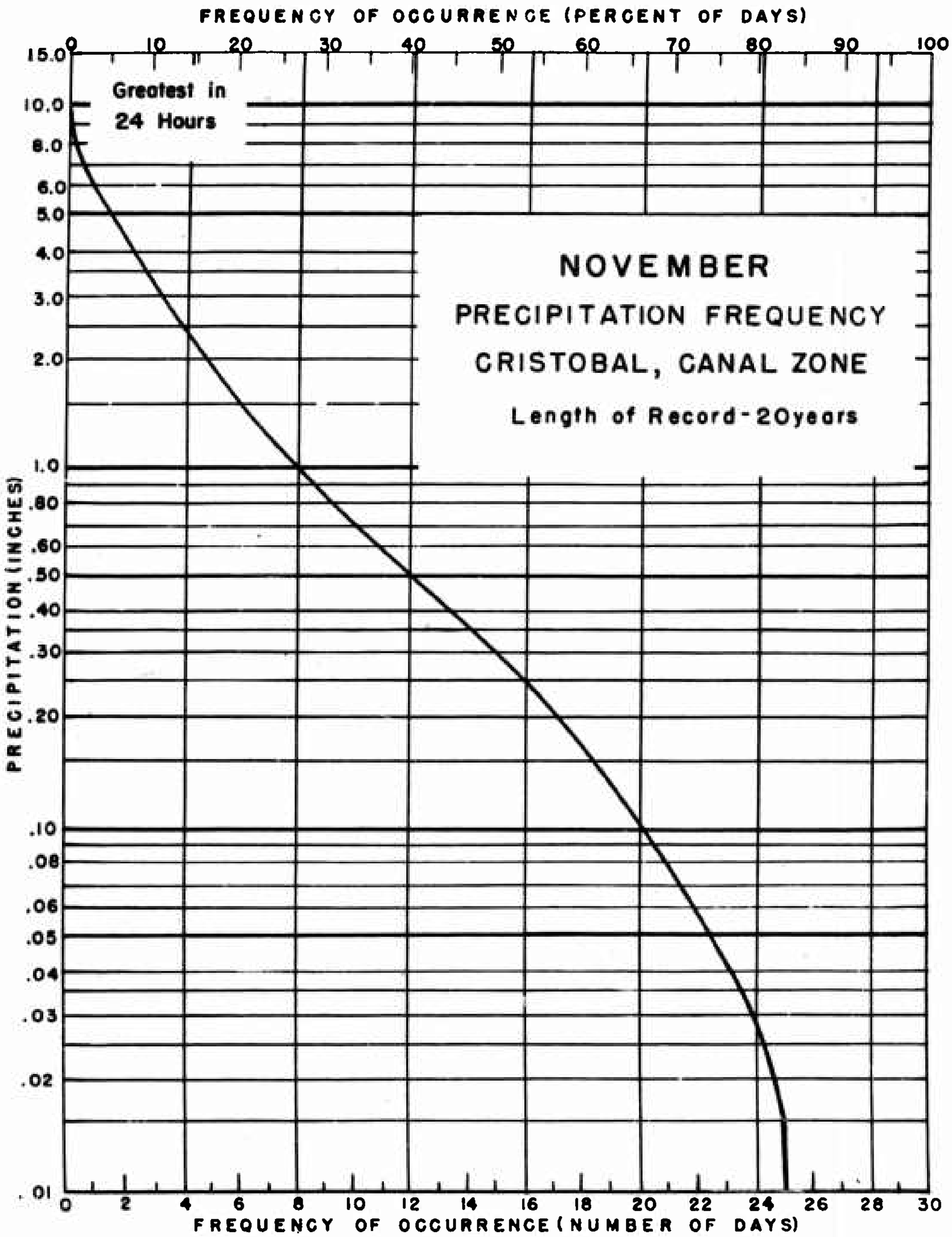
Figure 33



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 1.0 inches or more precipitation may be expected to occur 6 days during October (or approximately 20 percent of the days).

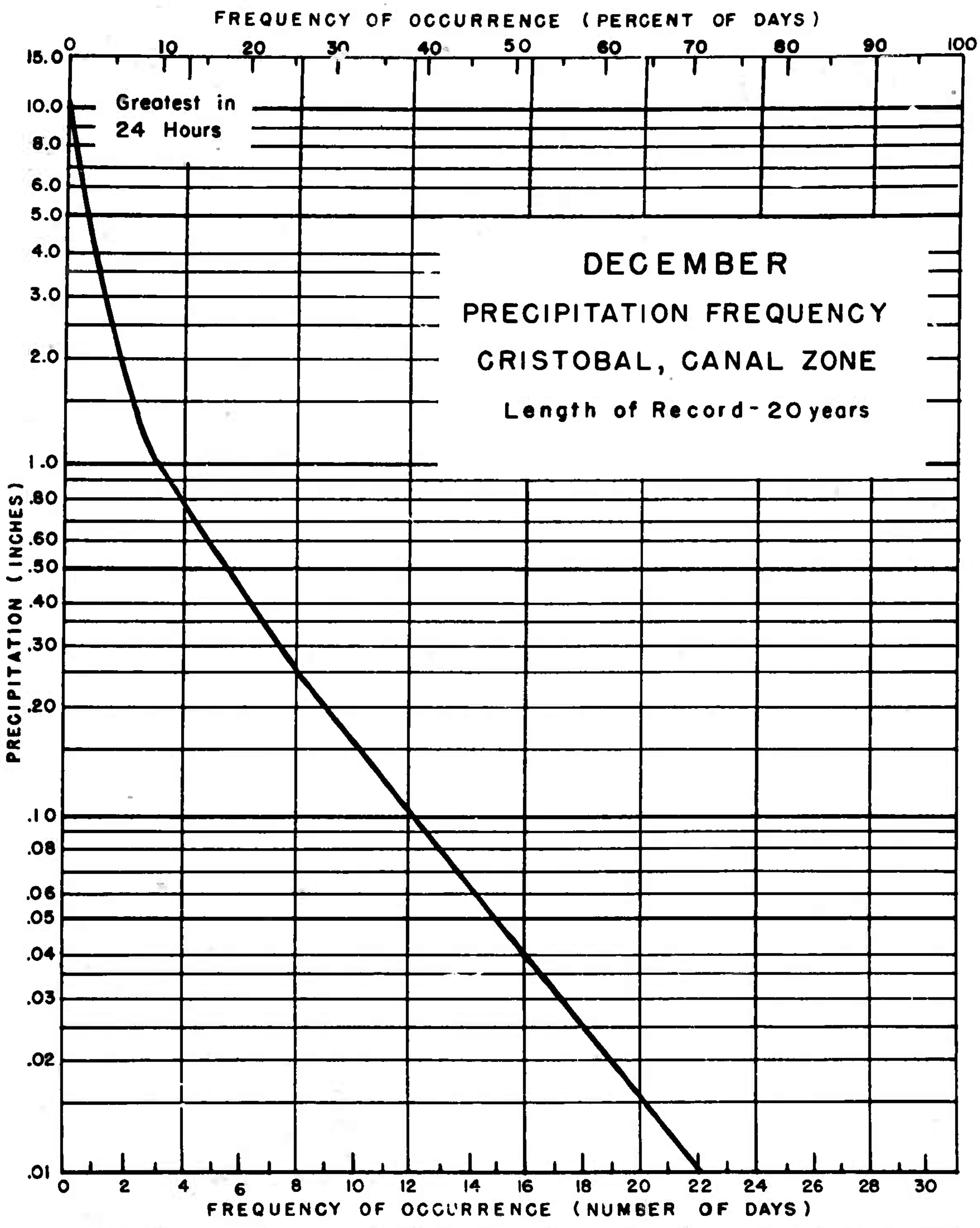
Figure 34



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 1.5 inches or more precipitation may be expected to occur 6 days during November (or approximately 20 percent of the days).

Figure 35



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: 0.25 inches or more precipitation may be expected to occur 8 days during December (or approximately 26 percent of the days).

Figure 36

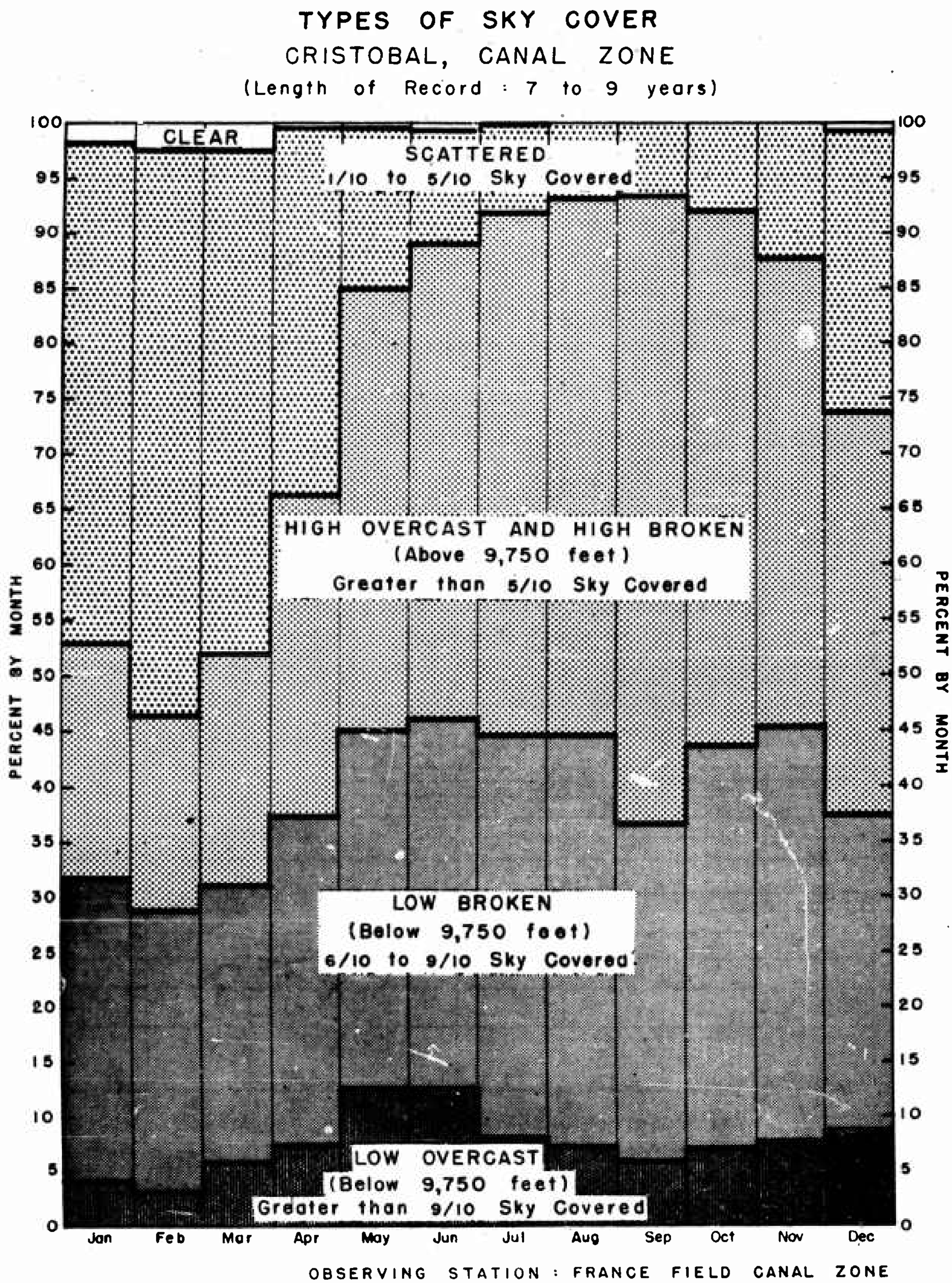

TYPES OF SKY COVER
CRISTOBAL, CANAL ZONE
(Length of Record : 7 to 9 years)
CLEAR
SCATTERED
1/10 to 5/10 Sky Covered
HIGH OVERCAST AND HIGH BROKEN
(Above 9,750 feet)
Greater than 5/10 Sky Covered
LOW BROKEN
(Below 9,750 feet)
6/10 to 9/10 Sky Covered
LOW OVERCAST
(Below 9,750 feet)
Greater than 9/10 Sky Covered
PERCENT BY MONTH
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
OBSERVING STATION : FRANCE FIELD CANAL ZONE

Figure 37

AMOUNT OF SUNSHINE
CRISTOBAL, CANAL ZONE
(Length of Record: 20 years)

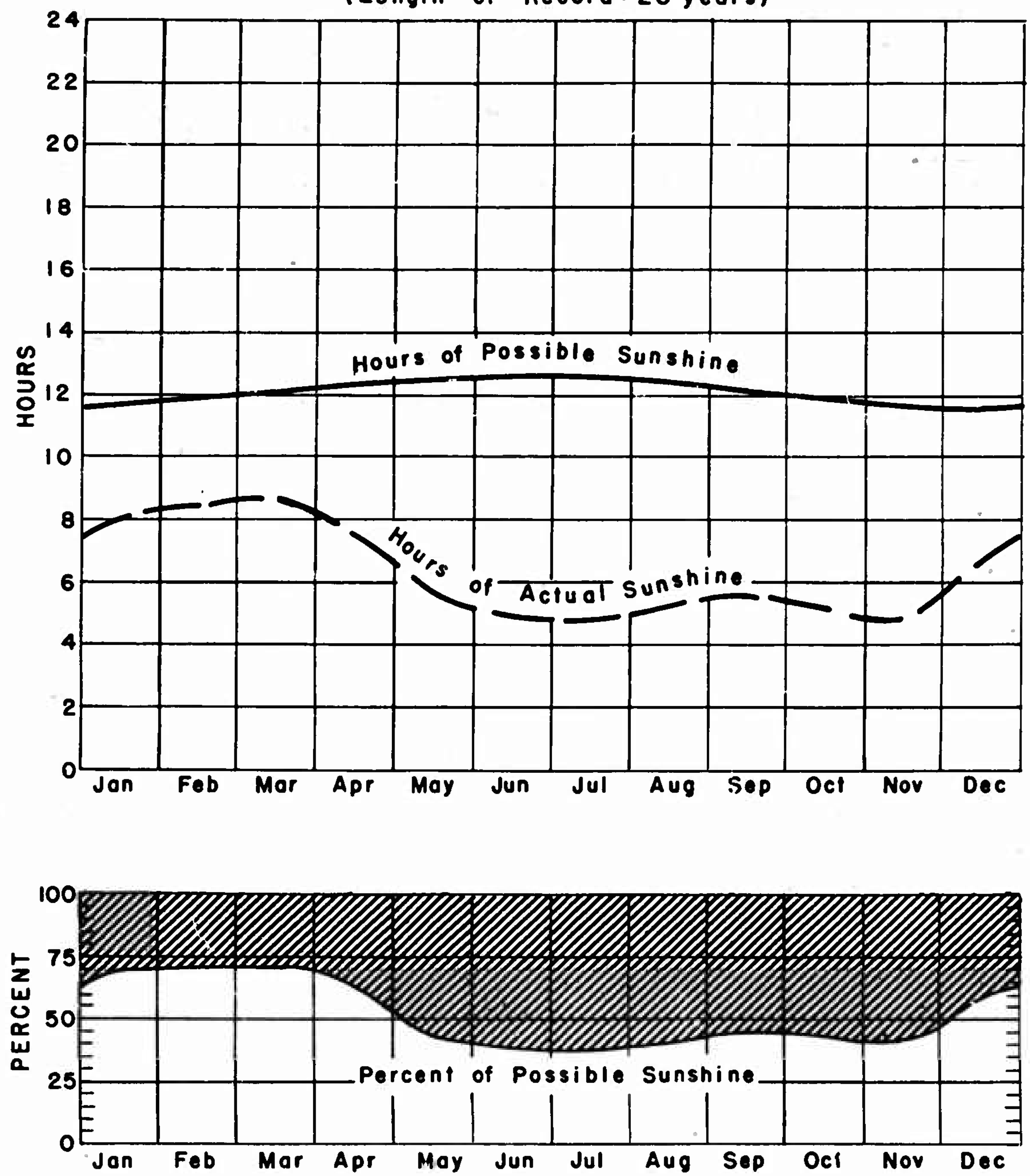


Figure 38

TABLE V : SOLAR RADIATION (LANGLEYS*) AT FORT SHERMAN TEST SITE, FORT SHERMAN, CANAL ZONE

(PERIOD OF RECORD: MARCH 1949 THROUGH FEBRUARY 1950)

Day	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	597	540	600	379	216	-	394	566	-	286	480	-
2	555	608	312	288	298	299	388	312	-	444	381	-
3	441	605	346	575	296	270	496	476	-	-	546	-
4	537	594	423	498	215	441	269	-	-	-	238	596
5	624	439	599	438	252	324	584	537	-	43	464	538
6	618	298	332	-	356	120	626	468	-	34	516	580
7	507	678	405	-	384	171	274	-	533	211	582	469
8	649	578	593	-	328	140	318	447	478	155	527	594
9	628	575	489	-	280	236	450	326	400	137	535	630
10	674	566	320	-	167	505	487	376	247	234	556	625
11	595	504	438	-	541	394	370	501	158	107	515	264
12	350	402	559	268	484	334	293	372	274	-	547	-
13	488	429	104	489	351	468	396	240	81	-	450	-
14	415	378	153	434	263	202	435	289	286	524	505	-
15	438	471	240	325	378	-	380	273	214	417	515	-
16	-	605	463	571	475	-	512	258	348	529	550	-
17	587	350	461	425	455	407	369	263	439	363	294	-
18	536	508	620	479	443	545	330	210	381	328	-	344
19	481	633	560	360	321	534	128	162	341	475	-	461
20	370	608	560	331	500	371	410	395	180	358	-	473
21	311	435	230	420	408	250	492	500	124	472	-	418
22	325	430	449	374	484	238	352	414	103	477	-	509
23	-	633	448	484	-	456	500	460	63	434	-	440
24	723	497	360	459	-	505	392	510	241	545	-	558
25	611	350	311	367	-	366	451	640	402	406	-	384
26	605	360	123	439	-	181	457	409	351	5[illegible]6	-	601
27	645	346	250	426	-	411	243	312	290	351	-	541
28	647	433	324	210	-	258	418	212	253	389	-	346
29	659	253	510	555	-	635	325	379	149	262	-	
30	543	171	430	309	-	550	175	576	301	505	-	
31	505		195		-	295		169		432	-	
Average	540	476	394	413	359	356	391	381	349	349	482	493

* 1 Langley = 1 gm - cal/cm^2 = 3.6869 BTU/ft^2

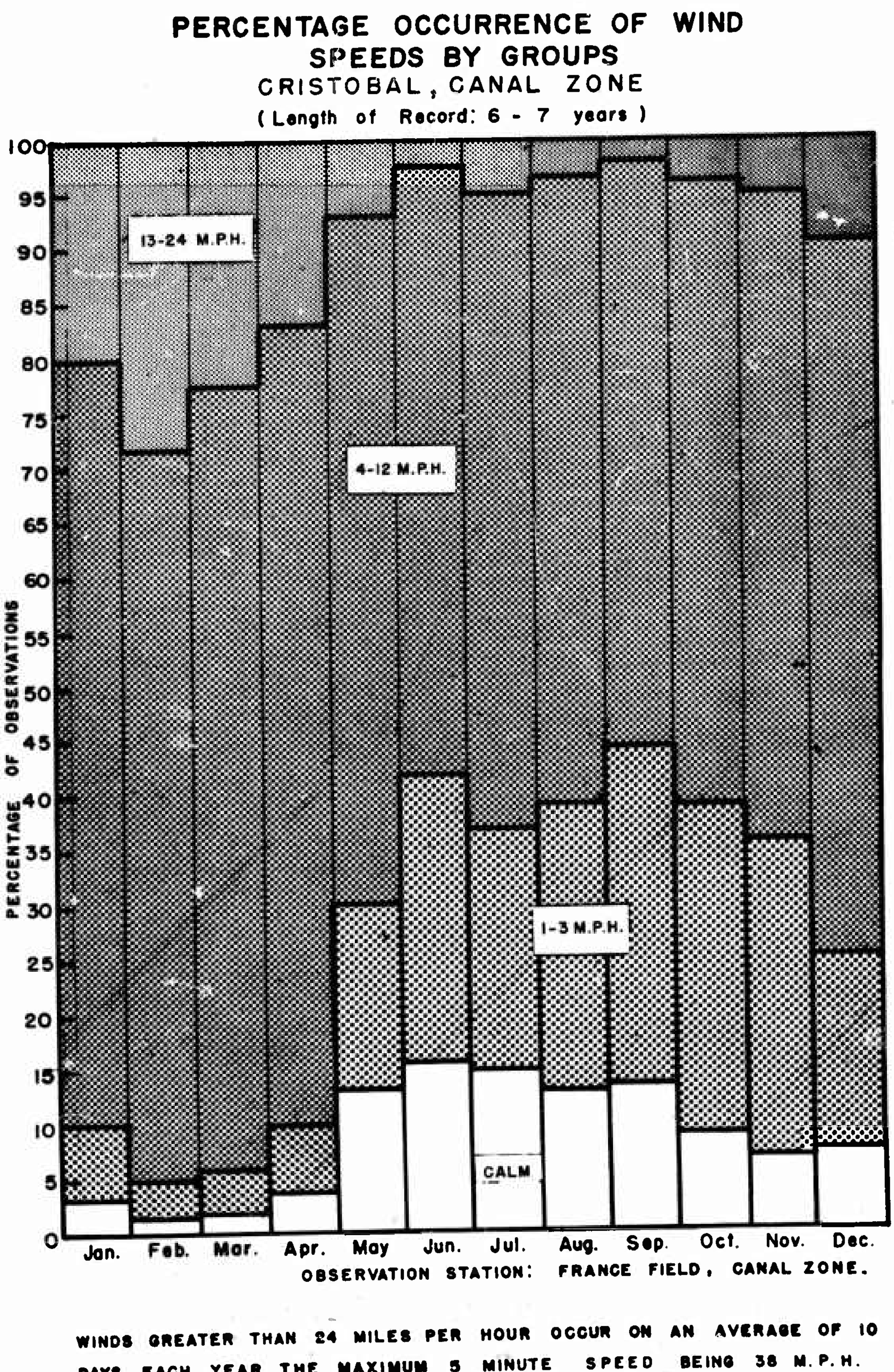

PERCENTAGE OCCURRENCE OF WIND SPEEDS BY GROUPS
CRISTOBAL, CANAL ZONE
(Length of Record: 6 - 7 years)
13-24 M.P.H.
4-12 M.P.H.
1-3 M.P.H.
CALM
PERCENTAGE OF OBSERVATIONS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
OBSERVATION STATION: FRANCE FIELD, CANAL ZONE.
WINDS GREATER THAN 24 MILES PER HOUR OCCUR ON AN AVERAGE OF 10 DAYS EACH YEAR THE MAXIMUM 5 MINUTE SPEED BEING 38 M.P.H.

Figure 39

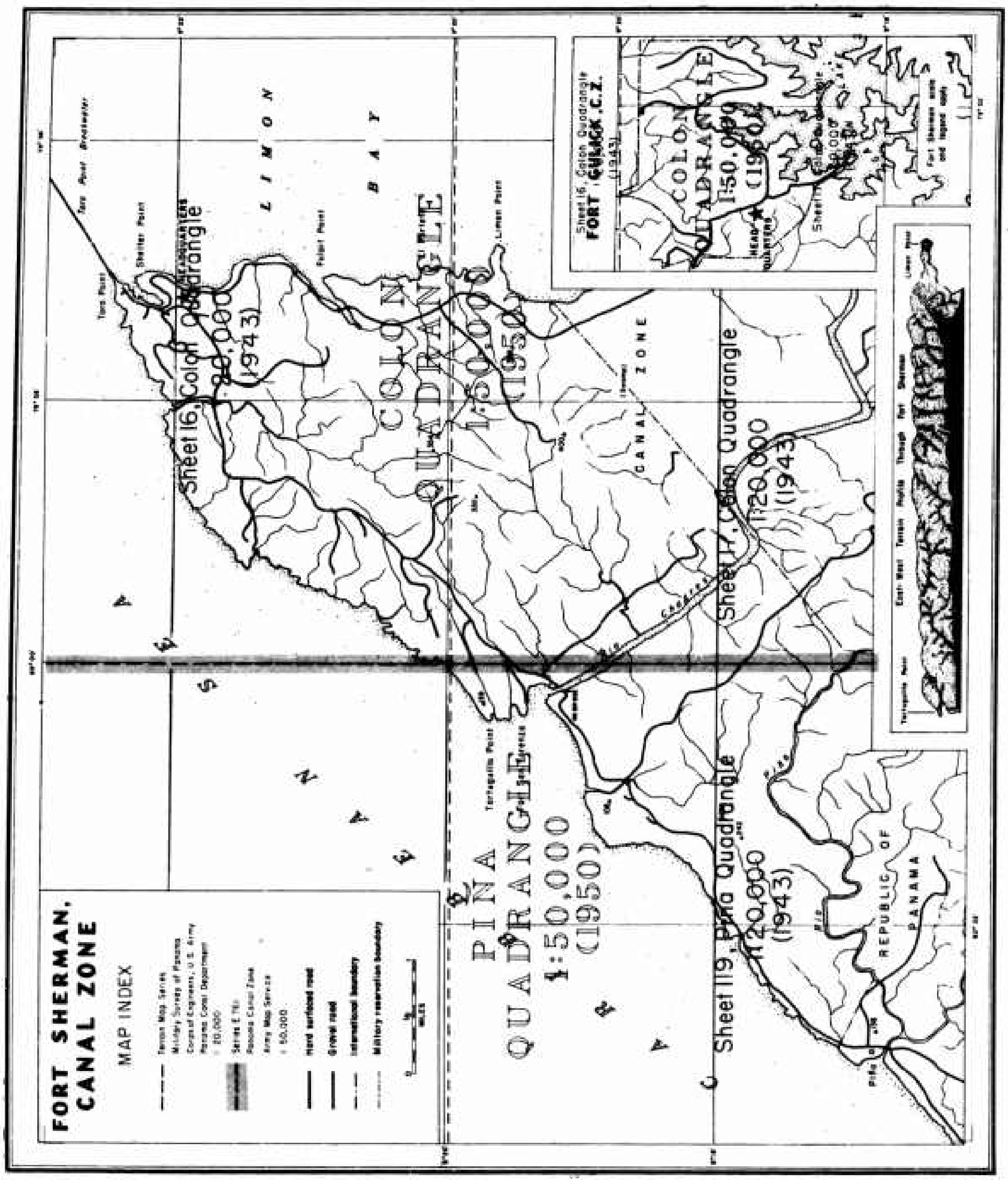

FORT SHERMAN, CANAL ZONE
MAP INDEX
COLON QUADRANGLE
1:50,000
(1950)
PINA QUADRANGLE
1:50,000
(1950)
Sheet 16, Colon Quadrangle
1:20,000
(1943)
Sheet 17, Colon Quadrangle
1:20,000
(1943)
Sheet 119, Pina Quadrangle
1:20,000
(1943)
L I M O N
B A Y
C A N A L Z O N E
REPUBLIC OF PANAMA

Figure 40

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